New Scientist

WEEKLY 25 May 2024

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CAN YOU REALLY BE ADDICTED TO ULTRA-PROCESSED FOOD?

SPECIAL ISSUE

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Predicting everything

Hear science writer Tom Chivers discuss the probability formula Bayes's theorem and its influence on modern life – from medical testing to creating novel kinds of artificial intelligence. Some even argue that Bayes's theorem underpins rational thought itself, suggesting it describes almost everything and is more than just a useful tool. Find out more at New Scientist Live on 13 October at London's ExCeL Centre.

newscientist.com/nslmag

Tour

Ancient caves, human origins: Northern Spain

Discover some of the world's oldest known cave paintings by torchlight in an idyllic part of Spain, including El Castillo, Las Monedas, La Peña, El Pindal and Tito Bustillo. Join former *New Scientist* editor-in-chief Emily Wilson to explore how our ancestors lived, played and worked 40,000 years ago. This seven-day tour starts on 18 June and costs £3250.

newscientist.com/tours

Podcast

Dead Planets Society

Leah Crane and Chelsea Whyte take outlandish ideas about how to tinker with the cosmos and subject them to the laws of physics. In this episode, they are shaking up the shape of our galaxy by asking what it would take to add extra arms to the Milky Way. After concocting this "octogalaxy", they try to create a galaxy shaped like a giraffe.

newscientist.com/nspod

ANGELINES CONCEPCIÓN/ALAMY

Ancient art Explore human origins and cave paintings in Spain

NASA/ESA

Extra galactic arms How to turn the Milky Way into an "octogalaxy"

Video

Bird in the hand

The Natural History Museum in Tring, UK, is home to one of the largest ornithological collections in the world, boasting bird skins, skeletons, eggs and nests. *New Scientist* was given a unique peek inside this vast collection and told how new technologies, such as artificial intelligence and chemical analysis, can help birds in the face of rapid environmental change.

youtube.com/newscientist

Newsletter

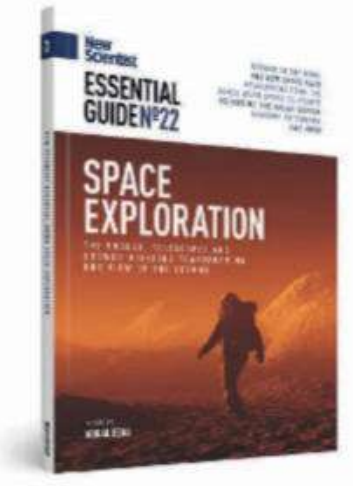
Wild Wild Life

Starlings and house sparrows are the two species in the UK most likely to live in your home, and they are both on the UK Red List for birds. Penny Sarchet considers the joy of letting wild animals live in your house and what effects housebuilding and home renovation trends are having on wildlife.

newscientist.com/wild-wild-life

Newsletter

"Swift bricks contain little holes for birds to nest in and can be built into the walls of a new house"



Essential guide

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Can you help the gibbons survive in their natural habitats?

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New Scientist and The LEGO Group's free social impact program, Build the Change, have teamed up to launch a competition to help gibbons survive in their fragmented forests. Open to UK residents* aged 11-14 the challenge is to design a solution to help gibbons navigate the threats they are facing.

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Addicted to addiction

A proposed definition of food addiction raises wider questions

WHAT links sex, drugs and sausage rolls? Depending on who you ask, all of them can be addictive to the point of harm. But while it is uncontroversial that people can become dependent on heroin or cocaine, the science behind many other supposed addictions isn't so clear cut.

For sausage rolls, the claim isn't that the pastry treats specifically can be addictive, but rather certain kinds of foods are high in fat, sugar, salt and other nutrients we crave. On page 10, we examine this new case for food addiction, and what it might mean for treating people if they have it.

It seems that new addictions are constantly cropping up – you might even say we are addicted to them. Some are calling for urgent action over an epidemic of young people becoming addicted to gaming or using social media, for example, while a few celebrities accused of sexual misdeeds say that they have sex addiction.

At the heart of many of these claims is dopamine, a molecule that surges in the brain when people take some addictive drugs. But while dopamine has become a buzzword relating to anything rewarding – from sugar to social media likes – its role in addiction is incompletely understood. It was once thought that dopamine itself causes pleasure, but we now think it is really a signal that the brain should pay more attention to an unexpected event.

"Dopamine is now a buzzword relating to anything rewarding – from sugar to social media likes"

And, perhaps surprisingly, there is no universally agreed definition of addiction. Rather than focusing on the brain, various medical bodies look at how proposed addictions affect behaviour. For instance, someone may be considered to have an addiction if they want to stop the activity but can't, if they experience cravings and if they tend to carry out the activity more and more. A person with gaming addiction may meet all those criteria, but someone who compulsively overeats seems unlikely to meet the last.

Really, it is unclear whether these definitions actually help. Perhaps, before we continue to create more mental health diagnoses, we should prioritise developing a better understanding of what addiction actually is. ▮

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Space

Astronauts take a trolley for a stroll

Navigating a volcanic field in Arizona while wearing mock space suits, NASA astronauts Kate Rubins and Andre Douglas are seen here pushing a cart of lunar tools. The recent field tests were to help NASA prepare for its planned Artemis campaign to land humans back on the moon, during which astronauts are expected to carry out science experiments on the lunar surface.

JOSH VALCARCEL/NASA/JOHNSON SPACE CENTER

Mathematics

Radical proof stumps mathematicians

A 1000-page proof of the complicated geometric Langlands conjecture has been published. It could provide key insights across maths and physics – if people can understand it, says **Alex Wilkins**

MATHEMATICIANS have proved a key building block of the Langlands programme, sometimes referred to as a "grand unified theory" of maths due to the deep links it proposes between seemingly distant disciplines within the field.

While the proof is the culmination of decades of work and is being hailed as a dazzling achievement, it is also so obscure and complex that it is "impossible to explain the significance of the result to non-mathematicians", says Vladimir Drinfeld at the University of Chicago. "To tell the truth, explaining this to mathematicians is also very hard, almost impossible."

The programme has its origins in a 1967 letter sent by Robert Langlands to fellow mathematician André Weil that proposed the radical idea that two apparently distinct areas of mathematics, number theory and harmonic analysis, were in fact deeply linked. But Langlands couldn't actually prove this and was unsure whether he was right. "If you are willing to read it as pure speculation, I would appreciate that," wrote Langlands. "If not – I am sure you have a waste basket handy."

> **"Explaining this to mathematicians is also very hard, almost impossible"**

This mysterious link promised answers to problems that mathematicians were struggling with, says Edward Frenkel at the University of California, Berkeley. "Langlands had an insight that difficult questions in number theory could be formulated as more tractable questions in harmonic analysis," he says.

In other words, translating a problem from one area of maths to another, via Langlands's proposed connections, could provide real breakthroughs. Such translation has a long history in maths – for example, Pythagoras's theorem relating the three sides of a triangle can be proved using geometry – by looking at shapes – or with algebra, by manipulating equations (see diagram, below).

RANDALL HAGADORN/IAS/PRINCETON

Robert Langlands came up with an idea to unify parts of maths in 1967

As such, proving Langlands's proposed connections has been the goal for multiple generations of researchers, leading to countless discoveries, including the maths toolkit used by Andrew Wiles to prove Fermat's last theorem. It has also inspired mathematicians to seek analogous links to Langlands's idea that might help. "A lot of people would love to understand the original formulation of the Langlands programme, but it's hard and we still don't know how to do it," says Frenkel.

One analogy that yielded progress is reformulating Langlands's idea into one written in the mathematics of geometry, called the geometric Langlands conjecture. However, even this reformulation baffled mathematicians and for decades was seen as very difficult to prove.

Now, Sam Raskin at Yale University and his colleagues claim to have proved the conjecture in a series of five online papers that total more than 1000 pages. "It's really a tremendous amount of work," says Frenkel.

The conjecture concerns objects that are similar to those in one half of the original Langlands programme, harmonic analysis, which describes how complex structures can be mathematically broken down into their component parts, like picking individual instruments out of an orchestra. But instead of looking at these with harmonic analysis, it uses other mathematical ideas, such as sheaves and moduli stacks, that describe concepts relating to shapes like spheres and doughnuts.

While it wasn't in the setting that Langlands originally envisioned, it is a sign that his original hunch was correct, says Raskin. "Something I find exciting about the work is it's a kind of validation of the Langlands programme more broadly."

"It's the first time we have a really complete understanding of one corner of the Langlands programme, and that's inspiring," says David Ben-Zvi at the University of Texas. "That kind of gives you confidence that we understand what its main issues are. There are a lot of subtleties and bells and whistles and complications that appear, and this is the first place where they've all been kind of systematically resolved."

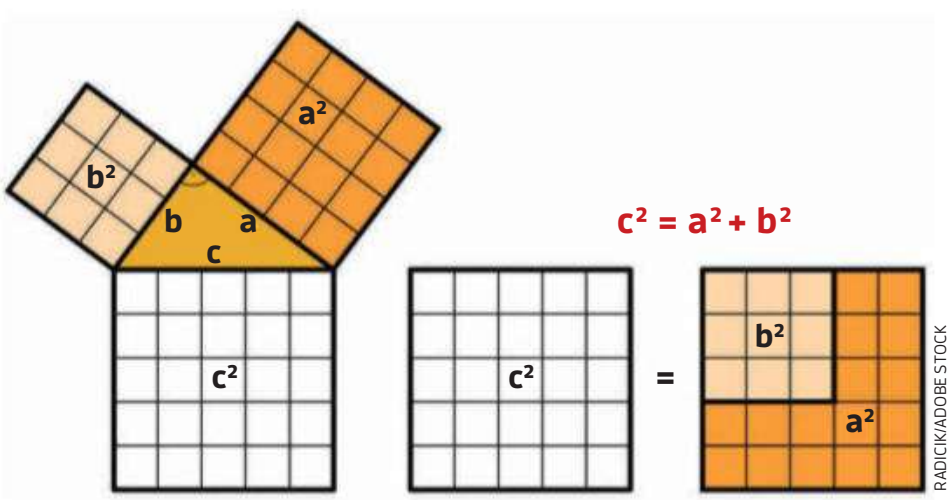
Proving this conjecture will give confidence to people hoping to make inroads on the original Langlands programme, says Ben-Zvi, and it might also attract the attention of theoretical physicists. This is because in 2007, physicists Edward Witten and Anton Kapustin found that the geometric Langlands conjecture appeared to describe an apparent symmetry between certain physical forces or theories, called S-duality.

The most basic example of this in the real world is in electricity and magnetism, which are mirror images of one another and interchangeable in many scenarios, but S-duality was also used by Witten to unite five competing string theory models, which are candidate theories of everything, into a single one called M-theory.

But before anything like that, there is more work to be done, including helping other mathematicians understand the proof. "Currently, there's a very small group of people who can really understand all the details here. But that changes the game, that changes the whole expectation and changes what you think is possible," says Ben-Zvi. ▮

Translational mathematics

The Langlands programme involves moving between different areas of maths. Pythagoras's theorem, relating the three sides of a triangle, is a much simpler example – it can be proved with geometry or with algebra



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Conservation

Solar-powered floating islands proposed to help regrow coral reefs

Madeleine Cuff

HERE'S an idea that could provide a sea change for coral. A team of researchers wants to create a cluster of floating, solar-powered islands to support reef restoration in coastal waters.

We already know it is possible to accelerate the recovery of damaged corals, or the growth of new coral colonies, by pumping an electrical current through seawater. This prompts minerals dissolved in the seawater to crystallise on structures, forming limestone rock that is the perfect habitat for young corals.

The approach, known as the Biorock process, has been used on hundreds of coral reefs around the world. But deployment has been limited to reefs close to shore because of the difficulty of running electricity cables out into the deeper ocean.

Lê Thanh Tài at Ho Chi Minh City University of Technology, Vietnam, and his colleagues have designed a system of three interconnected floating islands they say could be used to power the Biorock process at sea, with no need for terrestrial power supplies.

Each island would have a distinct function: one would feature a solar array to power the coral restoration efforts; the second would act as a research hub for teams monitoring the reef; and the third would be a "botanical garden", with a roof to collect rainwater as a water supply.

The islands would be hexagon-shaped, with each side measuring 30 metres across, and have a stainless steel frame and a composite outer surface.

The team's analysis, which hasn't yet been peer reviewed, suggests the islands could float and provide adequate water and electricity without relying on mainland supplies. Each system would cost about $2 million to build, Lê estimates (Research Square, doi.org/mw42).

"Our study has demonstrated the feasibility of our artificial islands," he says. "This highlights the potential for these islands to serve as viable platforms for coral reef restoration efforts."

The islands would sit in sheltered coastal bays where they would be protected from storms. They would transmit electricity to structures on the seabed where the coral would grow.

This Biorock reef in Indonesia uses electricity to boost coral growth

FRANCESCO RICCIARDI/ALAMY

Tsunami risk

"There are four anchors per island to prevent the whole system from drifting away without being under control and from being toppled over by large waves," says Lê, although he says an extreme event such as a tsunami would be likely to cause severe damage.

Alastair Bonnett at Newcastle University, UK, says the design looks sound. "Most artificial islands – and there are a lot in the tropics – are a real engine for destroying coral," he says. "To see a scheme that is about growing coral is great."

But floating islands usually only have a lifespan of 50 to 100 years. "If you are having schemes that need replacing every 50 years, that becomes an environmental issue itself," says Bonnett. ▮

Health

Heatwaves seem to be driving asthma flare-ups in children

HOT weather appears to be triggering more frequent hospital visits for children with asthma.

Symptoms of the lung condition, such as breathlessness and wheezing, are more commonly associated with cold weather. To investigate the impact of hot temperatures, Morgan Ye at the University of California, San Francisco (UCSF), and her colleagues studied electronic health data from UCSF Benioff Children's Hospitals.

The data included records on asthma hospitalisations and patients' addresses. The researchers used information from PRISM Climate Group at Oregon State University to obtain temperature records at the patients' homes every day from June to September between 2017 and 2020.

The researchers defined heatwaves in 18 different ways. By looking at the range of temperatures that occurred over these periods, they considered it a heatwave if it fell in the top 1 per cent of these temperatures, or the top 2.5 per cent, or the top 5 per cent, and so on.

Presenting their results at the American Thoracic Society conference in San Diego, California, last week, the researchers found that across all of the definitions, these temperatures were associated with 19 per cent higher odds, on average, of a child with asthma being admitted to hospital than when there wasn't a heatwave.

"As we see temperatures rise due to climate change, we can expect a rise in health-related issues"

Hot weather can contribute to smog and ozone pollution, which may irritate the airways, says Ye. "As we continue to see global temperatures rise due to human-generated climate change, we can expect a rise in health-related issues as we observe longer, more frequent and severe heatwaves."

Children are particularly vulnerable to extreme heat, says Stephanie Holm at the UCSF's Western States Pediatric Environmental Health Specialty Unit. ▮

Sonali Roy

Health

Is food addiction real?

Some doctors say people can be addicted to certain foods and this should be treated with abstinence, which goes against mainstream advice, reports **Clare Wilson**

IS IT possible to be addicted to eating unhealthy food? Yes, according to a group of doctors and scientists who are going against the medical mainstream to declare a provocative new way to think about overeating.

The idea isn't entirely new: a few researchers have been arguing for years that some people overeat so much that their relationship with food should be seen as an addiction. But because it seems different to other kinds of addictions, such as when people are dependent on alcohol or drugs such as heroin, many researchers and organisations are resistant to the concept. "An addiction is a dependence on something you don't need," says Duane Mellor, a spokesperson for the British Dietetic Association.

Obviously, we all need to eat. But those who argue for the idea of food addiction point to research in rats that found when they are allowed to drink sweetened water, it triggers the release of a reward-signalling brain chemical called dopamine, in a similar way to if the rodents are allowed to self-administer cocaine.

With food addiction, though, it is unclear what in our food should be classified as addictive. People may binge on cakes and chocolate, but they may also do so with savoury snacks, like peanuts or fried food. Some advocates of low-carbohydrate diets – such as Jen Unwin, a psychologist in Southport in the UK – say carbohydrate cravings can be triggered by anything that contains the nutrient, including ostensibly healthy foods like bread and pasta.

While there is no single widely agreed definition of addiction, most bodies, such as the World Health Organization, consider people's behaviour and how it affects their lives.

BAILEY-COOPER PHOTOGRAPHY/ALAMY

Certain "trigger foods" may be hard for some people to avoid

"When people talk about their problematic foods, they aren't talking about steak and broccoli"

SHUTTERSTOCK/NATALIA DANCHENKO

Someone may be considered addicted to cannabis or nicotine, for instance, if they crave the substance when they abstain, if they are unable to stop or if they continue to smoke it despite it harming their health.

Researchers use a questionnaire called the Yale Food Addiction Scale to measure these kinds of effects in relation to food, asking people how often they do things like eating to the point that they feel ill. Using this scale, some studies have estimated that as many as 14 per cent of adults have food addiction, but the concept remains contentious.

To boost understanding of the idea, 40 doctors and researchers have spent the past year developing a consensus statement, defining the condition and summarising the evidence. They unveiled it at the International Food Addiction Consensus Conference in London on 17 May.

One development is that the group says the condition should be reframed as addiction to ultra-processed foods. "When people talk about their problematic foods, they're not talking about steak and broccoli," says Unwin, who worked with the group. "It's always cakes, doughnuts, pizzas."

In its statement, the group says people with ultra-processed food addiction "use food in a way similar to drugs of abuse, obsess about food and/or engage in eating behaviours that become compulsive and often continue despite harmful medical and biopsychosocial consequences".

But combining the concept of food addiction with that of ultra-processed food could bring further problems, as the idea that ultra-processed food is a distinct and uniquely harmful category is also contested.

While it is uncontroversial that some kinds of processed foods like crisps and cakes promote weight gain, the big question is whether they do so because they were made in factories or because they are high in fat, salt and sugar. That matters because if people try to avoid all processed foods, this precludes things that most doctors would say are good for us, like wholemeal bread or pasta, baked beans and many types of premade sauces and meals.

It also presents a dilemma for dieters, because many commercial diet foods fall into the processed food category, says David Wiss, a dietitian in Los Angeles who helped formulate the consensus statement. "I think we're going to run into some pushback there."

Putting aside the ultra-processed food question, if food addiction does exist, it has implications for how affected people try to manage overeating. It suggests that they would benefit from completely abstaining from what they find to be their "trigger foods", like how people who are addicted to alcohol are advised to cut it out entirely, says Unwin.

That goes against common healthy eating advice, which is that banning foods can enhance their appeal, says Mellor. In this model, it is better to let yourself have occasional treat foods, but to stop eating them once you feel full, he says. "Abstaining is the opposite of intuitive eating."

Cutting it out

While there is no hard evidence on whether abstention or moderation is better, a recent study by Wiss, Unwin and their colleagues lends some support for abstention. This tracked people attending clinics for food addiction, which provided group and individual therapy sessions along with advice to cut out all their trigger foods and adopt a low-carb whole food diet. A report from 2022 found that after three months, this approach helped people reduce their food binging and lose weight.

Longer-term results were reported at the conference last week, finding that after one year, the participants continued to reduce their food addiction scores, as measured by the Yale questionnaire.

Wiss says a randomised trial comparing abstention with a more traditional moderation approach should be the next step.

For now, it remains to be seen whether food addiction advocates will convince the rest of the medical world.

Mellor says the idea of food addiction may be helpful for some people. "If you recognise you have got a problem with certain foods in your diet and you feel compelled to eat them, abstinence is a way of managing that," he says. "But I'm not sure the call to eliminate all sugar or eliminate all carbs is the right answer for everyone." ▮

Environment

Groundwater extraction is projected to peak by 2050

James Dinneen

THE amount of water humans extract from underground is set to peak within the next three decades as pumping depletes accessible stores. This could reshape the food and water systems that serve at least half the world's population.

Between 1960 and 2010, global groundwater extraction increased by more than 50 per cent, largely to irrigate crops. Today, one-fifth of all food is produced using groundwater. Much of this water is extracted from aquifers faster than they refill, decreasing water levels. This causes the land to sink, means contaminants build up in the remaining water and harms ecosystems fed by the aquifers. It also increases the cost of extraction, because wells must be drilled deeper and water pumps require more energy.

Previous studies projected this groundwater extraction would rise indefinitely, but they "did not have the human feedback in there", says Hassan Niazi at Pacific Northwest National Laboratory in Washington state.

Niazi and his colleagues have now projected how dropping water levels and rising pumping costs could affect extraction in the world's major water basins this century. They used a model that incorporates relationships between groundwater extraction, economic development, energy systems and climate change.

20%

Amount of the world's food produced using groundwater

The researchers modelled 900 scenarios to capture a range of possible futures.

On average across scenarios, they found that the volume of groundwater extracted peaked in about 2050 at 625 cubic kilometres of water, about twice as much as today. By century's end, extraction declined to near present-day level. The peak's timing and magnitude varied across scenarios, but nearly all forecasted a peak before 2100 (*Nature Sustainability*, doi.org/mw2g).

Some regions may face quicker declines. In most scenarios, extraction peaked before 2030 in 10 per cent of studied water basins, including in large areas of India, Pakistan and China. Extraction in some basins seems to have reached its maximum already. The researchers found declining extraction volumes in Missouri and California since 2010 and 2015, respectively.

"What is driving that peak really differs region to region," says Niazi. In California, for example, increasing pumping costs appears to be the main cause. In South-East Asia, shifts in precipitation and hotter temperatures due to climate change play a larger role, he says.

The researchers say it is impossible to drain all the planet's groundwater – they project people will pump less than 1 per cent of the water present in the top 2 kilometres of Earth's crust over the next century. But supplies that are easy to extract could run short, with knock-on effects.

Food prices could rise, for instance. That may spur more agriculture on rain-fed lands or compel drier countries to import water-intensive crops. Regions that haven't pumped much groundwater might pump more.

"Those changes aren't going to be easy," says Peter Gleick at the Pacific Institute, a non-profit research group in California. "You can't just move that agricultural production to somewhere else" in most cases, he says.

Alongside factors like climate change and a growing population, the impact on food availability could be "very alarming", says Matti Kummu at Aalto University in Finland. Food producers should switch to less water-intensive crops and use groundwater more efficiently as soon as possible, he says. ▮

Many farms in California rely on groundwater to irrigate their crops

PETER BENNETT/ALAMY

Analysis Direct air capture

Can machines that suck up atmospheric carbon truly help tackle climate change?

The direct air capture industry got a big boost with the opening of Mammoth, its largest plant yet, but can the technology scale up, asks **Madeleine Cuff**

HUMANITY has spent the past few centuries releasing ever greater amounts of carbon dioxide into the atmosphere – a state of affairs that must be reversed if we are to get to grips with climate change. Removing CO_2 in a process called direct air capture (DAC) has been on the cards for some time, but finally, after years of research and small-scale pilot projects, giant carbon-sucking facilities are becoming a reality. The question is, will the industry grow large enough, fast enough?

DAC got a big boost this month when Swiss company Climeworks switched on a new plant called Mammoth in Iceland. This can extract up to 36,000 tonnes of CO_2 a year from the atmosphere – living up to its name, at least when compared with its predecessor, Orca, which boasted a maximum capacity of 4000 tonnes per year.

CLIMEWORKS

The Mammoth direct air capture plant in Iceland is the largest in the world

Rapid expansion

The new plant instantly quadrupled global capacity for DAC and is a sign of a step change under way in the industry. Mammoth will only hold the title of world's largest DAC plant until next year, when the Stratos plant in Texas, built by a subsidiary of energy firm Occidental Petroleum using technology from Canadian DAC company Carbon Engineering, comes online. It will be able to extract half a million tonnes of CO_2 a year.

Steve Smith at the University of Oxford says Mammoth and Stratos are the start of a rapid expansion in global direct air carbon capture and storage (DACCS) capacity. "A dozen or so more DACCS projects are planned to go live in the next couple of years, by various companies," he says. "If these all materialise, DACCS capacity could be nudging 800,000 tonnes per year."

Overall, ambitions are high – both Occidental and Climeworks plan to be operating multiple plants with capture capacities of 1 million tonnes apiece by 2035.

This rapid expansion is being driven by two factors. The first is corporate interest in carbon removals, with the likes of Microsoft, Stripe and Coca-Cola buying DAC credits to help offset their own emissions. With the reputation of many traditional carbon offset schemes in tatters, DAC is seen by some large firms as one of the last respectable removal options.

Government policy has also been instrumental, particularly in the US. President Joe Biden's administration is spending $3.5 billion to support four DAC "hubs" in the US, including Stratos, as part of measures passed in the Inflation Reduction Act to drive carbon removal efforts across the country. US federal tax credits also provide support of up to $180 per tonne of CO_2 trapped and permanently stored via DAC, the first major policy of its kind anywhere in the world.

36,000

tonnes of carbon dioxide can be removed by Mammoth a year

But voluntary carbon credits and generous government subsidies will only take the industry so far. Pathways to limit warming to 2°C will require billions of tonnes of carbon to be removed from the atmosphere by mid-century. For DAC to make a meaningful contribution to that, "some form of regulation by governments" will be necessary to drive the growth of this sector, says Smith.

For example, in February, European Union officials outlined plans to create "a European single market for industrial carbon management" by 2050, to ensure all residual emissions from sectors such as livestock farming are balanced with equivalent removals. But the plans are still in their infancy and are yet to be approved by member states.

Another major hurdle is cost. For the DAC industry, the race is on to cut removal costs before government subsidies and corporate budgets run dry. Operators are hoping that by scaling up the size of facilities, the sky-high price of sucking carbon out of the air will come down rapidly, from around $600 to $1000 per tonne today to $100 to $200 per tonne within the next few decades. That would make DAC capable of delivering globally significant levels of carbon removal, most experts agree, but few are sure that such a dramatic price drop is possible.

"The science was done 50 years ago. This has always been about the ability to do things at industrial scale, cheaply," says David Keith at the University of Chicago. "The challenge is whether you can do it at an interesting cost, and I don't think we know the answer to that yet."

There are also reputational challenges to consider. Big oil companies, including Occidental, ExxonMobil and Shell, are all eyeing DAC as a way to justify squeezing more oil from reservoirs, reducing the net carbon footprint of their fossil fuel business on an ongoing basis. Rather than extending the lifespan of the fossil fuel industry, Smith stresses the focus should be on cutting global emissions and developing DAC as a way of tackling any residual, hard-to-abate emissions. He describes DAC as the "carbon equivalent of litter-picking: hard work, expensive, not the first-best way to deal with the problem, but necessary in our imperfect world".

Some people doubt DAC will ever make a meaningful contribution to cutting pollution. Howard Herzog at the Massachusetts Institute of Technology Energy Initiative believes the technology is "overhyped", citing uncertainty over its future costs and high energy demand.

Even Keith, who founded the DAC business Carbon Engineering, says other methods of carbon removal, such as boosting the carbon storage capacity of soils or ocean waters, hold at least as much promise. "Direct air capture is one of many different carbon removal pathways," he says. "I don't see it as being unique." ▮

Neuroscience

Life support switched off too early

Analysis shows continued support for people with brain injuries may let some partly recover

Moheb Costandi

A SUBSTANTIAL proportion of people with a traumatic brain injury who had their life support withdrawn may have survived and at least partially recovered if care had continued, a study suggests.

Traumatic brain injuries can occur due to a forceful blow, a jolt to the head or an object entering the brain, such as a bullet. Predicting an individual's outcome can be difficult, but some people recover and gain at least partial independence months later. Even so, families are often asked to decide whether to withdraw life-sustaining treatment within days of a severe injury.

To learn more about the potential outcomes of such events, Yelena Bodien at Massachusetts General Hospital and her colleagues collected data on people who were on life support following a traumatic brain injury at intensive care units in the US over seven-and-a-half years.

Of these people, 80 had life support withdrawn, and their outcomes were compared with those of 56 people in the same situation who continued with the treatment, some of whom went on to regain a certain level of independence.

The researchers identified factors associated with the withdrawal of life support, such as the person's age and sex. From this, they used an algorithm to calculate these people's likelihood of recovery had their treatment been maintained.

Electroencephalography (EEG) is used to assess brain function after an injury

DANCHENKO/GETTY IMAGES

These results suggest that 42 per cent of the people who had life support withdrawn may have survived and gained at least partial independence six to 12 months after the injury (*Journal of Neurotrauma*, doi.org/mwz6).

"Prognosis after TBI [traumatic brain injury] is highly uncertain, and expressing this uncertainty to families is very important," says Bodien. "Our results suggest that a more cautious approach is warranted when establishing prognosis [and that] careful consideration is required when making such an irreversible decision as withdrawal of life-sustaining treatment."

A lack of information about the long-term outcomes of traumatic brain injury is one reason why making a prognosis is difficult, she says, and this may cause clinicians to assume a poor outcome is probable and therefore recommend withdrawing life support.

Damian Cruse at the University of Birmingham, UK, says the results should be interpreted with some caution. "Decisions to withdraw are multifaceted and don't necessarily hinge on dichotomies of 'Will they be in a vegetative state or not?', but are more about whether the level of recovery is something that the patient would have been happy with," he says.

"That said, it is clear from this and other data that we are not as accurate in our predictions of recovery from the early period after injury as we would like to be, especially as these predictions will feed into families' difficult choices." ▮

Technology

VR headset can give you 360-degree vision like an owl

HUMANS can gain the ability to turn their gaze 360 degrees by using a virtual reality headset. The technique could help fighter pilots during dogfights.

Normally, we only get a 180-degree range of vision by turning our heads from side to side. You can increase this by moving your eyes and body, but that isn't always possible. Owls, by contrast, can turn their heads almost a full 360 degrees.

Now, Ganesh Gowrishankar at the Montpellier Laboratory of Computer Science, Robotics, and Microelectronics in France and his colleagues have developed a system that mimics this, allowing you to easily see all the way around with just small neck movements.

The researchers added a 360-degree camera to the top of an HTC Vive Pro Eye headset, which can measure head rotation and display a portion of the panoramic video feed from the camera.

They also included a layer of software that doubles the head rotation when selecting which part of the camera feed to show. This means that when the wearer turns their head 10 degrees, their field of view is rotated 20 degrees. When turning their neck 90 degrees to one side, they can see directly behind them (*Proceedings of the Augmented Humans International Conference 2024*, doi.org/mw2x).

Gowrishankar says test subjects quickly adapted to how far they needed to rotate their head and where they had to reach out with their hands to touch an object they saw, but also needed time to re-adapt after taking the device off.

"It doesn't overload your cognitive system. It provides you the agency to see where you want," he says.

The researchers think the set-up could be useful where people are seated and working in virtual or augmented reality. For instance, a fighter pilot could look all the way behind, or a robot operator could see a remote site in 360 degrees. ▮

"It doesn't overload your cognitive system. It provides you the agency to see where you want"

Matthew Sparkes

Neuroscience

Frozen human brain tissue revived without damage

Christa Lesté-Lasserre

A NEW technique has allowed scientists to freeze human brain tissue so that it regains normal function after thawing, potentially opening the door to improved ways of studying neurological conditions. It could also move us closer to freezing entire brains and bodies for cryopreservation and being able to safely revive them.

Brain tissue doesn't usually survive freezing and thawing. In an effort to overcome this,

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Some organoids were kept frozen for this many months

Zhicheng Shao at Fudan University in Shanghai, China, and his colleagues used human embryonic stem cells to grow self-organising brain samples, known as organoids, for three weeks. This was long enough for the development of neurons and neural stem cells that can become different kinds of functional brain cells.

The researchers then placed these organoids – which measured 4 millimetres across, on average – in different chemical compounds, such as sugars and antifreeze, that they suspected might help keep the brain cells alive while frozen and able to grow after being thawed.

After storing these organoids in liquid nitrogen for at least 24 hours, the team thawed them and looked for both cell death and the growth of neurites – the "branches" of nerve cells – over the following two weeks.

Based on the rates of cell death and growth associated with each compound, the researchers chose their top compound candidates, trying different combinations during freezing and thawing tests on a new set of organoids.

The combination that led to the least cell death and most growth was a blend of chemical compounds called methylcellulose, ethylene glycol, DMSO and Y27632 – which the researchers named "MEDY". They think MEDY interferes with a pathway that usually programs cellular death.

Shao and his colleagues tested MEDY in experiments involving brain organoids ranging from 28 days old to more than 100 days old. The team placed the organoids in MEDY before freezing – usually for 48 hours – and thawing them. The researchers then observed their growth in the lab for up to 150 days post-thawing.

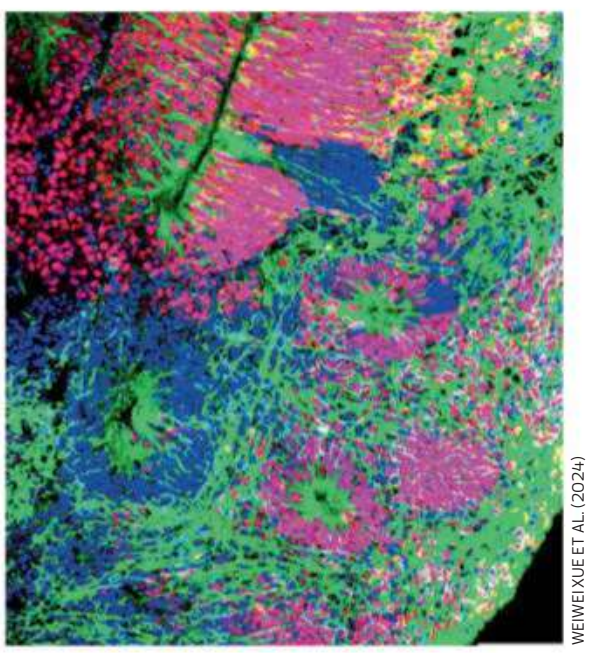
They found that the thawed organoids' appearance, growth and function were similar to those of organoids of the same age that had never been frozen, even among those that had been frozen in MEDY for 18 months. The team also saw similar results for organoids representing different regions of the brain (*Cell Reports Methods*, doi.org/gtvqmf).

Finally, the researchers took 3-millimetre cubes of brain tissue from a 9-month-old girl with epilepsy and placed them in MEDY before freezing and thawing them. The tissue maintained its pre-freezing structure and continued to remain active in a lab culture for at least two weeks after thawing.

Being able to freeze human brain tissues could lead to better studies of brain development in the lab for health research, says Roman Bauer at the University of Surrey in the UK.

João Pedro Magalhães at the University of Birmingham in the UK says he is impressed that the team's method prevented cell death and preserved function. "We know brain cells are very fragile and sensitive to stress," he says.

With more research, the work could one day lead to freezing entire brains, says Magalhães. "Thinking decades or centuries ahead, we can imagine patients being cryopreserved when they have a terminal condition or astronauts being cryopreserved in order to travel to other star systems." MEDY may be a step towards that, says Magalhães. ▮



WEIWEI XUE ET AL. (2024)

This thawed brain tissue has been stained to show which cells within it are still functioning

Technology

Buildings with weak points can better withstand collapse

Jeremy Hsu

INTENTIONALLY engineering structural weaknesses into a building can prevent catastrophic collapse. This counterintuitive strategy has limited damage to a two-storey concrete building in its first real-world experiment.

The segments of the building's connective structure are designed to break when stressed beyond a certain point instead of pulling down the rest of the structure.

"We want to prevent collapse, but if we cannot prevent collapse, we want to minimise the collapse," says Andri Setiawan at the Technical University of Valencia in Spain.

The prevailing design philosophy assumes that structural elements must be strongly connected to mutually support a building's weight if a column or load-bearing wall is knocked out. This principle has shaped modern building codes since the collapse of the 22-storey Ronan Point tower, which killed four and injured 17 in London in 1968.

The new study overturns this philosophy by adding "zones of calibrated weakness". These can still support a building experiencing limited damage, but in cases of catastrophic destruction, they can crumple to prevent a chain reaction.

Setiawan and his colleagues compiled a database with dozens of examples of catastrophic building failures, where a structure completely collapses. They then used computer simulations to find a balance between strong and weak structural connectivity. Next, the researchers did a full-scale test with a two-storey building made of precast concrete, which showed the new design could prevent wider collapse following smaller structural failures (*Nature*, doi.org/mwz7).

This strategy may work well for preventing collapse in low-rise buildings with large footprints, such as hospitals, shopping malls and sports stadiums, says Setiawan. ▮

Archaeology

Lost branch of the Nile discovered

Soil samples show an ancient river snaked through the desert near Egyptian pyramid cluster

Chen Ly

IF YOU thought ancient Egyptian pyramids were built in the desert, you have been living in denial. Many were built along a now extinct branch of the river Nile, geological surveys have revealed, which may explain why some pyramids, including the Great Pyramid of Giza, are clustered in a thin strip of inhospitable land.

"Since ancient times, the Nile has provided sustenance to Egyptian settlements, and it functions as the main water corridor that allowed for the transportation of goods and building materials in the past," says Tim Ralph at Macquarie University in Sydney, Australia. "For this reason, most of the key cities and monuments were built in close proximity to the banks of the Nile and its peripheral branches."

More than 100 pyramids were constructed between 4700 and 3500 years ago as grand tombs for Egypt's pharaohs. Thirty-one of these, including the pyramids of Dahshur, Giza and Saqqara, are dotted along the edge of Egypt's Western desert, several kilometres away from the Nile.

EMAN GHONEIM

Eman Ghoneim was part of the team that found a lost Nile branch by the Great Sphinx of Giza

To transport the enormous number of people and resources needed to build these pyramids, researchers suspected that the Nile may have once had an offshoot that flowed by the construction sites.

To investigate, Ralph and his colleagues looked at radar satellite imagery and land elevation data of the region. Depressions in the landscape indicated that the old water channel may have stretched 64 kilometres past the pyramid fields between the northern city of Giza and the village of Lisht in the south. It was also close to the ancient Egyptian capital of Memphis and the Abusir, Saqqara and Dahshur pyramid complexes.

"Most of the key cities and monuments were built in close proximity to the banks of the Nile"

Once the researchers had an idea of the branch's location, they took soil and sediment core samples along its path and discovered a riverbed of sand hidden under what is now farmland or desert.

"We guess that it was roughly between 200 and 700 metres wide, and at least 8 metres deep at its deepest," says Ralph.

Causeways that have been found around the 31 pyramids seem to end at the banks of this ancient Nile branch – a sign that the water channel was used to transport building materials thousands of years ago (*Communications Earth & Environment*, doi.org/mwn3).

The ancient offshoot, dubbed the Ahramat branch after the Arabic word for pyramid, dried up after a drought hit the region some 4200 years ago, says Ralph.

"People often imagine Egyptian pyramids being marooned in the middle of the desert," says Campbell Price at the University of Liverpool, UK. "This research seems to further demonstrate that they were in fact closely connected with the agricultural life of pharaonic Egypt – and the river Nile." ▮

Zoology

Weird lungless frog species does have lungs after all

A TINY frog from Borneo was thought to be the only frog species with no lungs – but it turns out they do actually have these organs.

In 2008, David Bickford at the National University of Singapore and his colleagues dissected 11 specimens of the rare Bornean flat-headed frog (*Barbourula kalimantanensis*). They were surprised when they couldn't find any lungs.

These frogs are fully aquatic and live in cold and fast-flowing streams. After running tests, the researchers reasoned that the lunglessness was an adaptation to their habitat, because large lungs filled with air would make the frogs more buoyant and susceptible to strong currents. Amphibians can breathe through their skin but this doesn't usually give them enough oxygen to forgo lungs, so this species was thought to be the first to get its fix solely from oxygen-rich rivers.

Now, David Blackburn at the Florida Museum of Natural History and his colleagues have taken another look at two of Bickford's specimens. High-resolution micro-CT scans revealed a respiratory system with small, thin lungs (*Current Biology*, doi.org/mw2s).

CHIEN LEE/NATUREPL.COM

The Bornean flat-headed frog does have lungs, just very small ones

"[We] were like, why is there a hole on the bottom of the mouth? That's not supposed to be there," says Blackburn. They had spotted the glottis, where the mouth connects with the lungs.

Bickford says he is "very happy" science has learned more about this rare, elusive species. He adds that these lungs are "very, very tiny" for the frog's size, so he still thinks that it largely relies on oxygen taken in through its skin.

"I'm very open to the possibility of the reduced lungs having some kind of function, but I'm sceptical," he says. ▮

Sofia Quaglia

Quantum physics

Entanglement may survive chaos of chemical reactions

Karmela Padavic-Callaghan

ODD quantum phenomena can survive the havoc of a chemical reaction, which could prove useful for quantum technologies or reveal surprising quantumness in nature.

"Typically, people describe chemical reactions as a very chaotic thing: you put a whole bunch of atoms in there, they do a little 'dance' and then when products are formed, they just fly out," says Lingbang Zhu at Harvard University. He and his colleagues set out to see what this does to the quantum properties of molecules.

Quantum objects can act as both particles and waves. The researchers focused on a property called coherence, which reflects molecules' wave-like character. Quantum entanglement, which links objects even across massive distances, is closely related to coherence. So, the experiment offers insight into entanglement's fate during a chemical reaction.

The researchers put potassium and rubidium atoms in an airless chamber and applied laser beams, magnetic fields and microwave pulses to cool them to just above absolute zero and combine them into molecules. These molecules spontaneously underwent chemical reactions, but Zhu and his colleagues controlled their initial quantum states, including their coherence and entanglement. After the reaction, they assessed the quantum properties of the products and found that the molecules kept their coherence, or wave-like property, behaving like two conventional waves (*Science*, doi.org/mwn2).

Yong Chen at Purdue University in Indiana says experiments like this open the door to quantum research where scientists aren't just uncovering quantum properties but finding ways to control them. ▮

For how to think about quantum entanglement, see page 41.

Plant biology

Orchids feed their young through underground fungal networks

Rowan Hooper

DANIEL SCHOENEN/IMAGE PROFESSIONALS GMBH/ALAMY

The common spotted orchid seems to send food to its seedlings

SOME orchids share resources with their seedlings, in what seems to be a form of parental care by plants.

The young seedlings don't have chlorophyll, so are unable to make their own food through photosynthesis, and biologists were in the dark about where the tiny plants actually got their nutrition from.

"This echoes the concept of the 'wood wide web' – the idea that plants share resources"

"Seedlings are often seen in clusters around adult orchids, and our results support the idea that this could be driven by a 'parental nurture' mechanism involving transfer of carbon compounds across generations," says Katie Field at the University of Sheffield in the UK.

Like most plants, orchids in the wild form links with soil fungi. Field and her team have shown that the adult orchids send parental care packages of food to seedlings, and they do it by making use of the so-called mycorrhizal network that results from these connections between roots and fungi.

Unlike the tropical tree-living orchids you might buy as house plants, terrestrial versions are notoriously difficult to cultivate. But Field and her colleagues managed to grow common spotted orchids (*Dactylorhiza fuchsii*), which are widespread across Europe, in the lab. They used a growth medium that included pineapple juice. They also introduced a fungal network into the medium that grew and connected adult plants to young orchid seedlings, or protocorms.

The researchers went on to expose the leaves of the adult plants to radiolabelled carbon dioxide, a form of the gas that is easily traced as it is metabolised, but blocked it from directly entering the growth medium, the seedlings and the fungal network.

After letting the plants grow for 48 hours, the team measured the carbon in the system and found that radiolabelled carbon was present in the seedlings as well as the adult plants, demonstrating that the adults had used the labelled carbon to make sugars by photosynthesis, which were then supplied to the juveniles (*New Phytologist*, doi.org/mwqx).

The work echoes the concept of a "mother tree" and the "wood wide web" – the idea that trees and other plants communicate and share resources through an underground mycorrhizal network. This idea has taken a scientific hammering recently, with suggestions that the evidence for some claims is lacking.

But Justine Karst at the University of Alberta, Canada, who has criticised some of the assertions around the wood wide web, says this orchid work does demonstrate carbon transfer through a common mycorrhizal network.

It remains to be seen which entity, if any, is in control of the transfer of compounds, though. As we learn more about fungal-plant interactions, we may find that language relating to human behaviour, such as competition, sharing and parental care and nurturing, isn't appropriate.

"Can the green plants 'nurture' juveniles if carbon allocation to juveniles is under control of the fungus?" asks Karst.

"Field studies – which are really difficult in common mycorrhizal networks – are now needed to find out if speculation about 'parental nurture' in plants can be justified," says Martin Bidartondo at Imperial College London. ▮

Astrophysics

Einstein's black hole idea was right

Observations of matter plunging into a black hole show his predictions were correct

Leah Crane

A STRANGE area around black holes called the "plunging region" has been spotted for the first time. This area, where matter stops circling a black hole and instead falls straight in, was predicted by Albert Einstein's general theory of relativity, but it has never been observed before. Studying plunging regions could teach us how black holes form and evolve, as well as reveal new information about the nature of space-time.

When matter gets too close to a black hole, it rips apart and forms an orbiting ring around it called an accretion disc. General relativity predicts there should be an inner boundary to the accretion disc past which nothing can orbit the black hole – instead, it should plunge straight in, rapidly accelerating to near the speed of light as it falls.

"It's like a river turning into a waterfall, and until now we've only been looking at the river," says Andrew Mummery at the University of Oxford. "If Einstein was wrong, then it would be stable all the way down – there would only be a river." Now we have had our first peek at the waterfall, suggesting Einstein was correct.

BURADAKI/ALAMY

We have glimpsed the waterfall of matter entering a black hole

Mummery and his colleagues spotted evidence of the plunging region around a black hole in a binary system called MAXI J1820+070, which is about 10,000 light years from Earth. They used data from the Nuclear Spectroscopic Telescope Array (NuSTAR), a space-based X-ray telescope, to build models of the light from the black hole's accretion disc.

They found the models only fit the data when they included the light emitted by matter in the plunging region in addition to light from the accretion disc (*Monthly Notices of the Royal Astronomical Society*, doi.org/mwmm). "Before, we sort of thought that anything that crosses this boundary would have no time to really radiate appreciably before it plunges into the black hole," so researchers wouldn't see anything, says Greg Salvesen at Los Alamos National Laboratory in New Mexico, who wasn't involved with this work. "But it turns out that this plunging region gives you extra light that you wouldn't have expected."

This extra light could solve a long-standing problem in X-ray astronomy, in which black holes appear to spin faster than theory predicts. The spin of a black hole and the brightness of the area around it are connected, so adding some extra light could bring the spins back in line with predictions. "Black hole spins tell us about all kinds of things, so if we could measure it better, we could answer loads of questions," says Salvesen.

That includes questions about the nature of gravity and space-time itself, because plunging regions are some of the most extreme regions of space we can observe. The plunging region is just outside the event horizon, beyond which the gravitational forces are so strong, no matter or even light can escape.

"It's like a river turning into a waterfall, and until now we've only been looking at the river"

"Technically, if the matter had a rocket it could escape the plunging region, but it's doomed – its orbit has become unstable and it's rapidly accelerating toward the speed of light," says Mummery. "This stuff has about as much chance of coming back as water off the edge of a waterfall." ▮

Archaeology

Nomads thrived in Greece after collapse of the Roman Empire

AN ANALYSIS of pollen from Lake Volvi in Greece has unexpectedly revealed that nomads thrived in this region for centuries after the collapse of the Roman Empire.

Adam Izdebski at the Max Planck Institute of Geoanthropology in Germany and his colleagues have been studying sediment cores from the lake. Changes in the abundance of the kinds of pollen in sediment layers can record how the nearby vegetation changed over time.

In some other places around the Mediterranean, the team has found signs of reforestation after the collapse of the Western Roman Empire around AD 476. But at Lake Volvi, from around AD 540, the team found less tree pollen but more pollen from plants associated with nomadic livestock herders. These nomads were returning to the same areas seasonally, so they planted some crops, such as barley.

"We have this moment when the Roman agriculture disappears… but you don't get reforestation – you actually get less forest very quickly," says Izdebski. "The landscape was dominated by pasture animals even in the high mountain areas. This was a complete shift from how the Romans farmed the lowlands."

ONLY FRANCE/ALAMY

Pollen records reveal a Grecian landscape that was dominated by pasture

This means those earlier farmers moved away, died or adopted a nomadic lifestyle, he says.

Greece was nominally under the control of the Eastern Roman, or Byzantine, Empire at the time of this shift. It is known that the region was raided by Bulgar nomads around AD 540, but it wasn't known that nomads lived there. The findings also correlate with an account of a Byzantine emperor being ambushed by nomads around AD 700.

"It seems that there was a local society that didn't want any emperor to be around," says Izdebski, who presented the findings at the meeting of the European Geosciences Union in Vienna, Austria, last month. ▮

Michael Le Page

Analysis Generative artificial intelligence

OpenAI is beating Google in the AI race, but who wants the future they are building?

Big tech firms are competing to have the most exciting artificial intelligence products, but generative AI remains hampered by issues, says **Chris Stokel-Walker**

WHEN OpenAI released its ChatGPT tool in November 2022, it was a shot across the bows of Google, with generative artificial intelligence promising a new way to access the world's information beyond search engines. Since then, the rivalry between these firms has only grown, with both announcing new services this week. While there are signs that OpenAI is winning this race, is either company aiming for a future anyone actually wants?

On 13 May, at a live demonstration event, OpenAI unveiled GPT-4o, a new AI model capable of more human-like interactions. The AI appeared able to converse with company representatives live on stage, as well as analyse live video footage that was streamed to it using smartphone cameras, responding to what it "saw".

Google unveiled similar capabilities the following day, showing off how its Astra project could review computer code and fix errors, as well as find a missing pair of glasses in an office, all through the camera on a Google smartphone.

Searching for success

The firm also announced it will be further integrating AI-generated results into its search engine, summarising content from web pages that previously would have been linked to from a search results page, reducing the need for users to click through to websites.

These competing announcements, made just a day apart, had echoes of a similar situation in early 2023, when Google unveiled its Bard chatbot (now rebranded as Gemini) to try to head off the early success of ChatGPT, whose release appeared to have taken the search giant by surprise. "Google has been in this space for quite a long time and had a lot of models that were almost ready for the marketplace before OpenAI opened up the market with ChatGPT," says Mike Katell at the Alan Turing Institute in London.

Of the two offerings, Google's has generally been seen as less significant. "The [recent] announcements do help cement OpenAI's position at the top in terms of generative AI," says Carissa Véliz at the University of Oxford. "When you think 'generative AI', you think GPT-4, and now you're going to think about this new model."

This lead is borne out in data: according to market intelligence firm AppMagic, while the ChatGPT app was downloaded onto smartphones 3.2 million times this February, Google's Gemini was only downloaded 630,000 times that month.

The web versions of these AIs show the same trend, with ChatGPT attracting 1.8 billion visits to its site in April, according to analytics company SimilarWeb, while Gemini managed less than a quarter of that number.

SHUTTERSTOCK/VITO AMATI

Open AI, headed by Sam Altman (above), is vying with Google (below) for dominance over a new market

3.2m
ChatGPT app downloads in February

630k
Google Gemini downloads in the same month

DAVID PAUL MORRIS/BLOOMBERG VIA GETTY IMAGES

OpenAI also seems more confident about the abilities of its products. In data accompanying the release of GPT-4o, OpenAI claims that its new model can outperform all competitors, including Google's Gemini, while Google's demonstration only claimed that its AI could match the performance of other models.

Uncertain future

Even if OpenAI is pulling ahead, we should keep in mind that the success of the generative AI revolution is far from certain. The field is so new that companies aren't competing for market share or customer loyalty, but merely to have the latest products, says Katell.

And there are suggestions that this product invention is stalling. Ahead of the GTP-4o announcement, OpenAI had to quell gossip that it was about to unveil GPT-5, a long-rumoured, purportedly more powerful model capable of reasoning.

Instead, the technology it presented may make the issues of anthropomorphising its AI system even more pronounced by giving it human-like interactivity, without necessarily improving its basic capabilities or preventing it from making things up.

Despite the bluster of the past few years, it is also worth noting that only 23 per cent of US adults have ever used ChatGPT, according to surveys by the Pew Research Center. "It's still very unclear to what extent [this technology] matters," says Véliz. "The majority of people haven't actually used generative AI tools, and there are some reasons to think that it might end up being less helpful than some people thought it would be." ▮

Energy

Sunlight-trapping device hits 1000°C

ENGINEERS have developed a device that can generate temperatures of over 1000°C (1832°F) by efficiently capturing energy from the sun.

Emiliano Casati at ETH Zurich in Switzerland and his colleagues added a 300 millimetre layer of quartz around a receiver designed to have sunlight concentrated onto it. The quartz allows light energy to pass through it but blocks thermal energy. This means that as silicon in the receiver heats up in the sunlight, the quartz traps heat and reduces energy loss.

The team tested the receiver in a facility that simulates sunlight using LEDs and the silicon absorber reached 1050°C (*Device*, doi.org/mwj5). Such devices could be used as a green alternative to burning fossil fuels to make materials such as steel and cement. **Chen Ly**

JOAN J. SOTO-ANGEL, AWI & UNI BERGEN

Technology

AI headphones focus in on just one voice

PROTOTYPE noise-cancelling headphones allow you to select which background noise to drown out, letting you put an "audio spotlight" on a specific voice.

Shyam Gollakota at the University of Washington in Seattle and his colleagues have attached microphones to a set of headphones to record sound and pass it to an artificial intelligence system that can work on a smartphone. The AI is trained on many examples of 20 types of sound, including alarm clocks, crying babies and birdsong. You can select each category in an app, allowing it to pass through the headphones or be blocked. The AI can also home in on a specific voice and exclude all other noise, the researchers told a meeting of the Acoustical Society of America and the Canadian Acoustical Association. **Matthew Sparkes**

Marine biology

Invasion of jellyfish could disrupt Arctic ecosystems

THE jellification of the Arctic may have already begun. As northern waters warm and sea ice melts due to climate change, many species of jellyfish could expand towards the North Pole, disrupting ecosystems.

Predicting impacts will be hard, says Charlotte Havermans at the Alfred Wegener Institute in Germany. "Some of these species – we know nothing about their ecology."

She and her colleagues combined several datasets on the distribution of eight species of jellyfish and their gelatinous relatives across the greater Arctic. They looked at a representative set of species, ranging from the hydrozoan *Aglantha digitale* – just a centimetre or two in length – to the lion's mane jellyfish (*Cyanea capillata*, pictured above), which can grow tentacles more than 30 metres long.

They modelled how the range of each species would shift in the second half of this century in response to warming waters, melting ice and other changes to the ocean under a medium-to-high emissions scenario.

Most species would see their range expand as well as shift toward the North Pole, mostly due to the loss of sea ice. The lion's mane jellyfish had the largest predicted expansion, with its range almost tripling in area (*Limnology and Oceanography*, doi.org/mwj4).

There are already indications jellyfish have started going north. In some fjords in the Norwegian archipelago of Svalbard, jellyfish have outcompeted cod, disrupting fisheries, says Havermans. The impacts will depend on how other species respond: added competition could be detrimental to some, but for others, the jellyfish could be a source of food. James Dinneen

Really brief

NEA SALO

Why some cats look like salty liquorice

The gene variant behind a distinctive colour pattern seen in cats in Finland (pictured above), named salmiak after a type of speckled liquorice, has been found. It is a mutation close to the *KIT* gene, which is associated with white hair patterns in many domestic animal species (*Animal Genetics*, doi.org/mwj6).

One-day workshop boosts teens' mood

A school workshop based on cognitive behavioural therapy run for just one day led to improvements in the mood and stress levels of teenagers aged 16 to 18 for at least six months, a trial of 900 pupils at 57 schools in England has found (*The Lancet Psychiatry*, doi.org/mwkc).

Insect eyes to give robots a wide view

A team has replicated the architecture of compound insect eyes using nanowires made from a crystal material called perovskite. An overlapped pair of the artificial eyes create a field of view of 220 degrees. They could give drones, robots and driverless cars a very wide field of vision (*Science Robotics*, doi.org/mwkd).

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ADVERTORIAL

Rethinking soil, revolutionising irrigation

The Irrigation Solar Attenuation Harvest (ISAH) system captures rainwater in underground attenuation tanks for use as irrigation or as a flood alleviation system. The patented technology is fully designed in the UK and installed at Writtle University, Essex.

Traditional agriculture relies heavily on irrigation, often drawing vast quantities of fresh water. This can strain water resources and contribute to salinisation. ISAH solution lies in their unique ability to enhance the soil's natural water retention capacity. Their bio-treatment fosters a healthy soil microbiome, leading to improved soil structure and increased porosity. This allows the soil to act like a sponge, soaking up and storing rainwater more effectively.

The benefits are twofold. Reduced reliance on external irrigation systems translates into significant water savings, a crucial step towards sustainable agriculture. Additionally, by capturing more rainwater, ISAH's system helps mitigate the effects of drought and unpredictable weather patterns.

"It's a win-win," says Kevin O'Grady, ISAH CEO. "We're helping farmers conserve water while ensuring their crops have access to the moisture they need to thrive."

ISAH's technology is not a one-size-fits-all solution. They are collaborating with farmers in diverse regions to tailor their system to specific soil types and weather conditions. This customisation ensures optimal water retention and maximises the impact on irrigation needs.

Looking ahead, ISAH envisages a future where their bio-treatment becomes an integral part of rainwater harvesting systems. By combining their soil enhancement with rainwater capture techniques, they aim to create closed-loop systems that minimise reliance on external water sources altogether.

The road to widespread adoption requires educating farmers about the long-term benefits of this novel approach. However, the potential for water conservation and drought resilience is undeniable. ISAH's bio-revolution in agriculture offers a glimpse into a future where water scarcity does not cripple crop production, but where the land itself becomes a partner in sustainable water management.

You can find out more by visiting the Future of Food and Agriculture stand at New Scientist Live 2024. For more details go to: live.newscientist.com

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Simon Ings on *Sting*, a horror sci-fi about a pet spider **p30**

Letters
Offsetting can still be done, but it costs a lot **p31**

Comment

Be more female

From infections to brain injuries, the female body is more resilient than the male. It is time to reassess the "weaker" sex, says **Cat Bohannon**

WOMEN and children first, right? The idea that the female body is more vulnerable is pervasive in the public imagination. But in biology, it is increasingly clear the male body has that dubious honour. So let's talk a bit about innate female strength, shall we?

When it comes to fighting off invading pathogens, female bodies come up victorious – and not just in relation to covid-19. Across the human lifespan, they are less likely to contract most infections. At first, scientists weren't sure about this: in many places in the world, boys are taken to health clinics sooner, which can lead to a diagnosis bias. But the signal we see is too strong, and it holds in many lab animals, too. Female animals are simply more resilient – so long as they aren't pregnant. That is when all sorts of bodily mayhem happens, much of which can cause the risk of death to outpace that of male animals.

ADRIÀ VOLTÀ

But barring pregnancy and the postpartum period, female resilience holds true. We know that in many mammals, including humans, males tend to die sooner than females, but on the way, they are diagnosed with cancer more often. This is usually chalked up to them having a single X chromosome instead of two, making X-linked mutations more potentially malignant as these wouldn't be kept in check by a non-mutated partner. But female resilience seems to function at nearly every tier of a body's organisation. It even influences how individual cells decide whether or not to stay alive, which can really matter when those cells are part of the brain.

People with mild to moderate traumatic brain injuries (TBIs) fare worse if they are female, for example, but those with severe TBIs do worse if they are male. This is something we are just starting to learn, in part because people who experience intimate partner violence are both more likely to be female and more likely to be hit in the head than the average person.

One reason might be that male brains tend to respond to the necrotic death of their injured cells a bit differently, with the whole brain inflaming more dramatically. Male cells also have less of the antioxidant glutathione available, making them more vulnerable to damage from free radicals, which can lead to malfunction and cell death. For doctors in emergency care, the outcomes of these differences can be striking: male TBI patients often don't do as well as female ones, and this has been seen in rodent models, too.

Well, that's the case so long as the menopause hasn't happened, when the female body becomes more vulnerable than the male one to things like severe ischemic stroke – technically not a TBI, but a condition that should, in principle, follow similar patterns in terms of lesion severity and brain-wide inflammation. Yet those who are post-menopausal often do worse after a stroke. Before menopause, they are protected, perhaps because of their higher estrogen and progesterone profile, which is already known to be protective against, for example, many types of tissue damage.

A number of labs are testing whether treating male TBI patients with female sex hormones might help them stave off some of the damage. There are outstanding questions: which hormones will help, how much should be used, when should they be given and at what point in the body. These are a hot topic of applied research for skin injuries, too. Female patients who are pre-menopausal tend to heal lacerations faster, and adding topical estrogen improves wound healing in both sexes. The solution, in other words, to helping male patients stay alive and healthy might just be making their bodies – temporarily, locally, in a controlled fashion – be more female.

This is hardly the story we usually tell about the sexes. Maybe the boys should get in the life rafts first? For their safety. ▮

Cat Bohannon is the author of *Eve: How the female body drove 200 million years of human evolution*

Future Chronicles

A home in the trees

This week, we visit carbon-negative cities of the late 21st century: forest homes formed from giant sequoia, genetically altered for rapid growth. **Rowan Hooper** is our guide

Future Chronicles explores an imagined history of inventions and developments yet to come. Rowan Hooper is the podcast editor at *New Scientist* and author of *How to Spend a Trillion Dollars: The 10 global problems we can actually fix*.

Invention
Living-tree homes

Time stamp
2070

Tagline
The ultimate in eco-living

IN THE second half of the 21st century, the first living city was established in urban forest around Portland, Oregon. Sequoia City comprised a grove of 40 trees, including a hospital tree, schools, farms and recreation facilities (zip lines, slides and altitude swings). As they grew, residential trees eventually each housed dozens of families, living in custom-grown rooms made of living plant tissue. Children raised in Sequoia City saw no distinction between humans and other lifeforms. To them, ecology – the study of life in relation to its environment – was something they understood in their bones. That they were connected to nature went without saying; their intimacy was innate.

Sequoia City was a demonstration settlement, established to provide the proven mental health benefits of living in nature, to support the storage of carbon in living trees and soils and to tackle the extinction crisis.

It was inspired by ecologists who had discovered other species that had domesticated plants to live in. *Philidris* ants in Fiji sow seeds of *Squamellaria* on the branches of large trees. The ants tend the seedlings, which, as they grow, form large, hollow structures called domatia. The ants are saved the effort of building a nest and move into the domatia. The *Squamellaria* produce fruit too, which the ants eat. Descendant ants plant more seeds taken from their crop and the symbiotic cycle carries on.

The planners behind Sequoia City saw what the ants were doing and thought it looked like a good idea. Inspiration also came from living tree cities in science fiction, such as Cixin Liu's *Remembrance of Earth's Past* trilogy.

Giant sequoia are some of the largest organisms to have existed on our planet. They can live for up to 3000 years and grow up to 90 metres tall. In the early 21st century, their numbers fell in their native range in the Sierra Nevada mountains of California due to the climate crisis, but they continued to grow well in wetter, more northerly regions such as northern Europe and the Pacific Northwest. Oregon was chosen as the first location for a living city.

There were a few problems to overcome in developing the residential trees. The biggest was the slow growth of sequoias. Although faster-growing than

"Sequoia City was inspired by other species that had domesticated plants to live in, such as *Philidris* ants in Fiji"

the likes of oak, sequoia still take at least 100 years before they are big enough to live in.

However, the genome sequence of giant sequoia was well known, and our understanding of the genetics of plant growth was sophisticated enough even back in the 2020s to locate genes related to fast growth. With careful gene editing, it was possible to create sequoia that develop ultra rapidly. The key DNA sequences came from eucalyptus, one of the fastest growing trees, and bamboo, which, despite being a grass not a tree, supplied some important traits that enabled the development of a suitable species of sequoia.

The resulting trees formed their own version of domatia, encouraged by inserting guiding bars into the plant tissue. Different sized rooms could easily be grown, and windows installed. Bathrooms and toilet facilities were fully plumbed. Sewage was processed by specialised microbes and recycled into soil at the base of the tree and in the numerous gardens high in the tree itself.

Epiphytes – plants growing on other plants – are diverse and important parts of the forest ecosystem. In Sequoia City, garden zones and farm zones grew a range of squashes, cereals and beans, which the residents both consume and trade. Small cherry and apple trees themselves grew in orchard zones supported by the giant sequoia. Water farms on the trees deployed bromeliads, ferns and mosses to trap moisture from the air and send it down pipes to storage domatia. Electricity was supplied by wind and solar installations on individual domatia and on specialised power trees.

The success of Sequoia City spawned a series of copies around the world that used gene-edited species native to their region: Oak City and BeechTown in the UK, Bamboo MegaCity in southern China and Gum Towns, made of eucalyptus, in Tasmania and New South Wales in Australia. The domestication of the baobab and its subsequent gene-editing for accommodation led to spectacular Baobab towns in Ghana, Kenya and Sudan. By the end of the 21st century, satellite surveys of tree cover confirmed a significant fraction of previously deforested land had been regreened, and estimates suggested that the tree cities had contributed to a large reduction in atmospheric carbon dioxide. Studies reported that species diversity and population sizes had returned to levels not seen since the 19th century.

Tree children, immersed in the arboreal high life, traditionally got their first pair of wings – modified hang gliders – at age 10. ▮

Future Chronicles appears monthly. Up next week: Chanda Prescod-Weinstein

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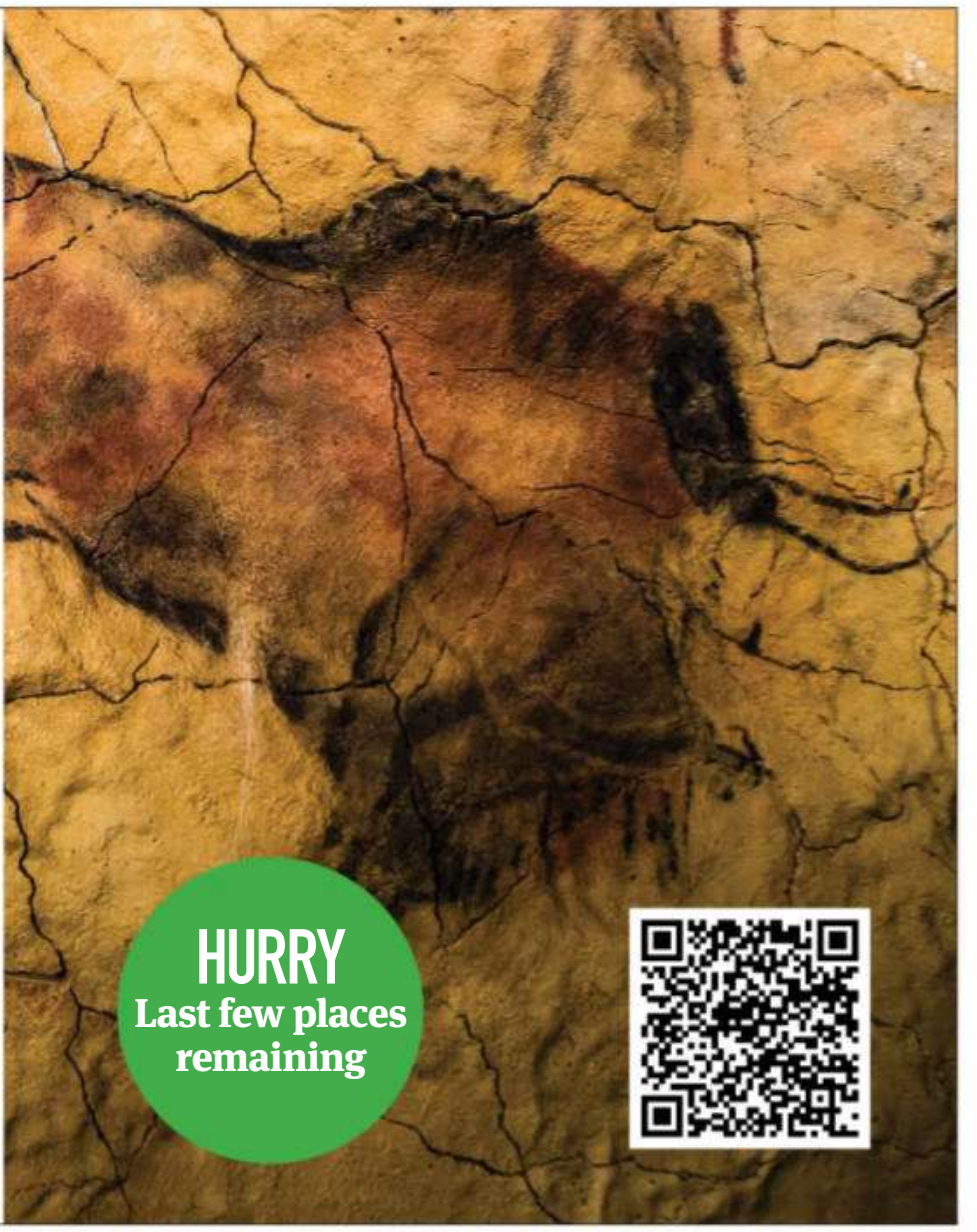

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Say cheese!

Photographer **Johanna Turner**

AS THE glow of Pasadena, California, lights up the valley beneath the San Gabriel mountains, this handsome black bear has been captured by the flash of a trail camera.

Wildlife photographer Johanna Turner connected her camera to a motion sensor to take the shot, which went viral after she posted it on social media. "This shot is a long exposure, so each time an animal comes, I only get one chance at a photo – so everything needs to work perfectly. Which is rare," she says.

Turner's goal is to show wildlife in its natural habitat. "I also want people to know that even around a megacity, we have beautiful wildlife that need their habitat protected," she says. "It is quickly disappearing." The San Gabriel mountains were made a national monument in 2014, with President Joe Biden recently extending the protected area to include the portion where this bear lives.

Turner says she has many fun photos of bears, which often accidentally end up in these sorts of "selfies", but she is most interested in mountain lions, or cougars (see below). "[They] are very difficult to capture on camera, mostly because there simply are more bears than lions... here," she says.

Alison Flood

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The power of AI for environmental stewardship and optimised industry

Behind the scenes, industrial artificial intelligence is transforming the efficiency and performance of companies. But the bigger picture is the implication for global sustainability

"We've never had such powerful tools to solve the challenges we face in sustainability," says James Cole, Chief Innovation Officer at the Cambridge Institute for Sustainability Leadership (CISL), in the UK. "Artificial Intelligence (AI) systems have the potential to help us understand the world in all its complexity to optimise industrial processes for holistic business, social and environmental outcomes."

The arrival of AI across the industrial sector has been heralded as the next great industrial revolution. But unlike past revolutions, which typically accelerated the consumption of resources, AI offers the opportunity to slash waste while boosting efficiency to levels only previously dreamed of. Within this context, global technology company, Siemens, is working to strengthen the emerging link between AI-optimised industry and environmental stewardship as society pushes towards net-zero carbon emissions.

At heart, AI is software that performs tasks traditionally requiring human intellect, such as understanding text, identifying complex patterns, modelling processes, and making predictions. But in an industrial context, AI systems must be engineered for reliability and security. That allows them to be built into the industrial backbone of economies, optimising and improving processes in everything from healthcare and mobility to power generation and infrastructure.

Take water management. One way to improve water sustainability is to lose less of it through leaks. Yet ageing pipes and ground movements make leaks inevitable. "About 30 per cent of the drinking water the world produces is wasted – a shockingly high figure," says Adam Cartwright, Siemens' Industry Strategy Director for Software in Water and Waste Water. "Every time you avoid losses, you're not only saving money but better managing precious water resources."

VA SYD is one of Sweden's largest water companies supplying drinking water to over half a million customers. Previously, it was losing 10 per cent of its water but had no means of detecting small leaks.

Water Intelligence

By training an AI model on historical data from VA SYD's water network, the Siemens Leak Finder application learned to identify and locate leaks, even small ones losing just 0.25 litres per second. That allowed VA SYD to reduce leaks to a world-leading level of less than 8 per cent.

Meanwhile, Siemens is working with Yorkshire Water and the University of Sheffield, using AI to protect the environment at the other end of the water cycle. In combined sewage systems, stormwater runoff and household sewage together flow to water treatment plants. And in times of intense rainfall, combined sewer outlets are designed to release excess water and sewage into rivers to prevent flooding in public areas. One challenge is that blockages in pipes can lead to unnecessary releases, but these obstructions are hard to detect (see diagram).

To address this, Siemens developed a blockage-predicting AI trained on data from thousands of sensors on Yorkshire Water's sewer outlets, in combination with rainfall data. It learned what a properly functioning sewage network looks like under different weather conditions. When its monitoring system detects flows in the network behaving unexpectedly, it simulates potential blockages in different locations to work out where a real blockage may be developing.

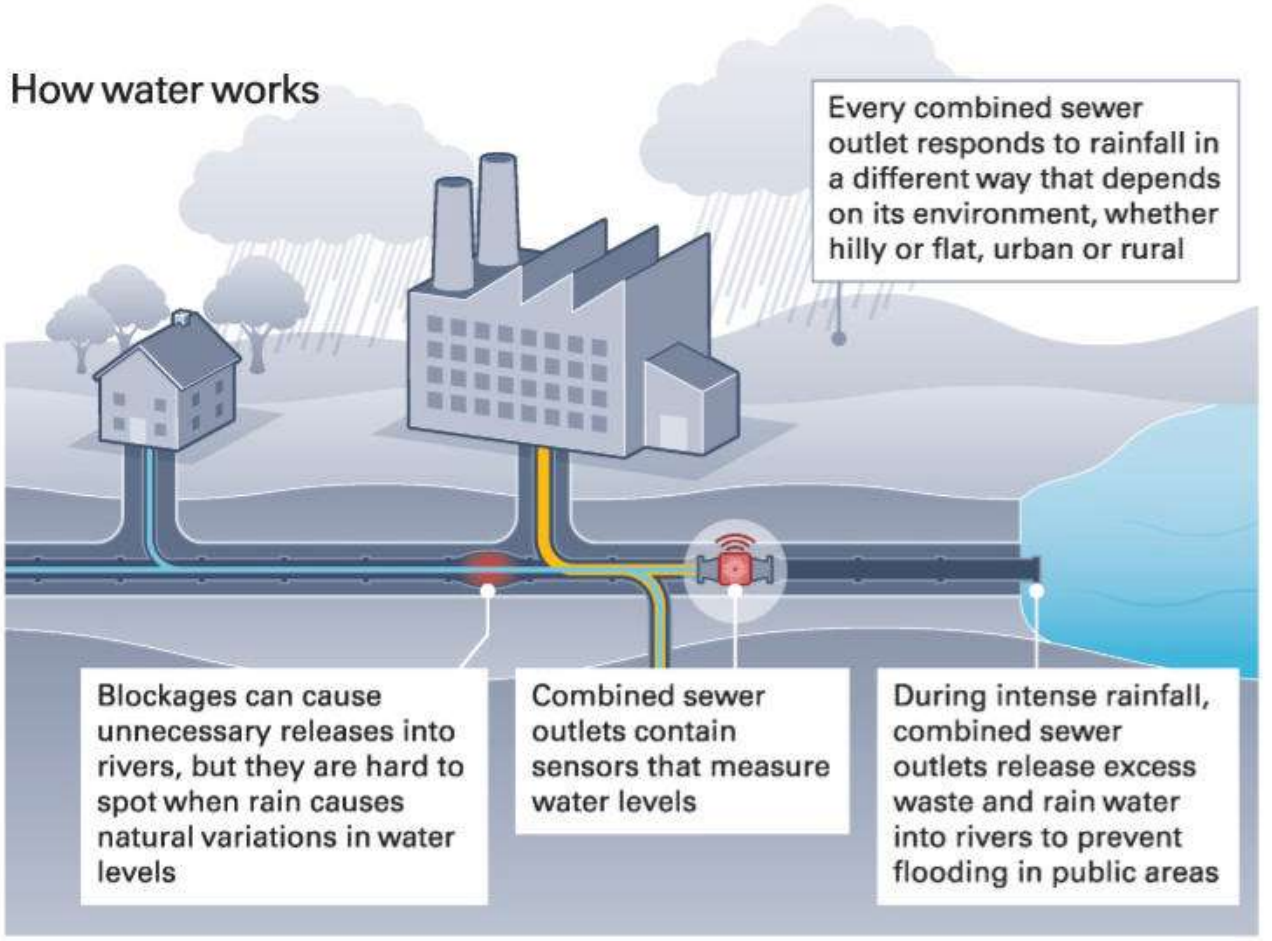
The predictor finds 90 per cent of potential issues; three times more effective than traditional, statistical approaches. And it provides as much as two weeks' warning of impending blockages, while halving the previous rate of false alarms.

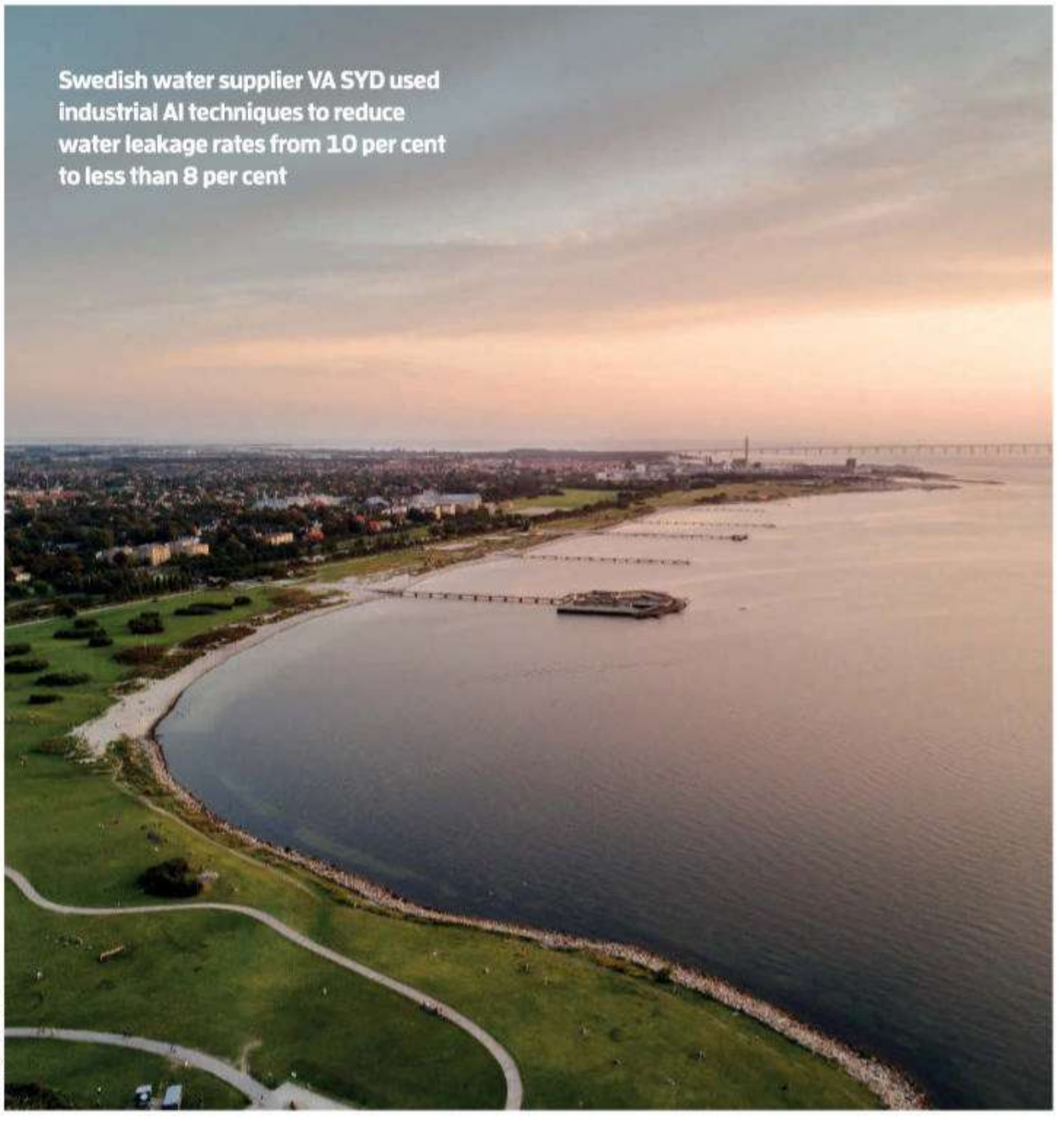
Looking ahead, Cartwright considers the potential for AI and digital technologies to reduce carbon and environmental impact by more carefully managing water and energy use. "Pumping water accounts for 2-3 per cent of a country's power use," he says. By ensuring that this pumping is done when energy is at its cheapest and greenest, industrial AI can reduce costs for water and increase resilience for both sectors.

AI is already helping manage the environmental impact of another key part of modern society's infrastructure: data centres. Their energy usage is significant, much of it used to keep their thousands of servers cool.

But consider Greenergy Data Centers' facility in Estonia. Already powered solely by renewable energy, the company further reduced its environmental footprint and energy costs using AI.

Servers produce heat depending on their workload but this can change more quickly than conventional cooling systems can react


How water works
Every combined sewer outlet responds to rainfall in a different way that depends on its environment, whether hilly or flat, urban or rural
Blockages can cause unnecessary releases into rivers, but they are hard to spot when rain causes natural variations in water levels
Combined sewer outlets contain sensors that measure water levels
During intense rainfall, combined sewer outlets release excess waste and rain water into rivers to prevent flooding in public areas



Swedish water supplier VA SYD used industrial AI techniques to reduce water leakage rates from 10 per cent to less than 8 per cent

KENTAROO TRYMAN

to. To combat this, Siemens developed AI-supported software that uses real-time temperature and airflow data collected by sensors all over the data centre, in addition to information on server workload. The system can then anticipate cooling needs to maintain optimal temperatures throughout the facility.

"When we first launched the system, it improved our efficiency by approximately 30 per cent at the push of a button," says Kert Evert, Chief Development Officer of Greenergy Data Centers.

It's an example of AI being part of the solution to one of its own challenges, given concerns over the amount of energy AI requires. Here Pina Schlombs, Sustainability Lead, Siemens Digital Industries Software, notes the outlook of AI computing efficiency is improving drastically.

Consider also an AI model in the industrial space that accelerates product design for optimal environmental lifetime impact or increases resource and energy efficiency, she says. "With a holistic perspective, we can gauge whether the sustainability benefits of AI outweigh the resources to train and run it."

To realise AI's benefits within any industry, continues Cartwright, the first step is making full use of existing infrastructure, data and sensor networks. If additional hardware is required, it should be easily linked to existing hardware and asset-management software through secure, standard protocols. "This interoperability is key to supporting the diverse, evolving needs of industrial applications," says Cartwright. Organisations can then benefit from the convergence of AI with other technologies; its ability to help master complex problems at speed and scale.

CISL's accelerator programmes reflect this potential, having supported over 350 startups in the past three years, including those showing the power of AI to solve complex challenges. Monumo, for example, is revolutionising electric motor design, enabling more design simulations to be run than conventional approaches – finding faster answers to energy efficient vehicle design.

All this makes AI an ally in humanity's effort to achieve a smarter, environmentally friendly future. Cole agrees. "AI has the potential to help us make better decisions through greater understanding. This facilitates better collaboration across industries, to foster alignment on how we realise a sustainable tomorrow."

Further reading:
www.siemens.com/artificial_intelligence

I think we're alone now

What does being alone mean in a social world? Two solitude researchers and a journalist make a great start at teasing apart the complexities, finds **Elle Hunt**

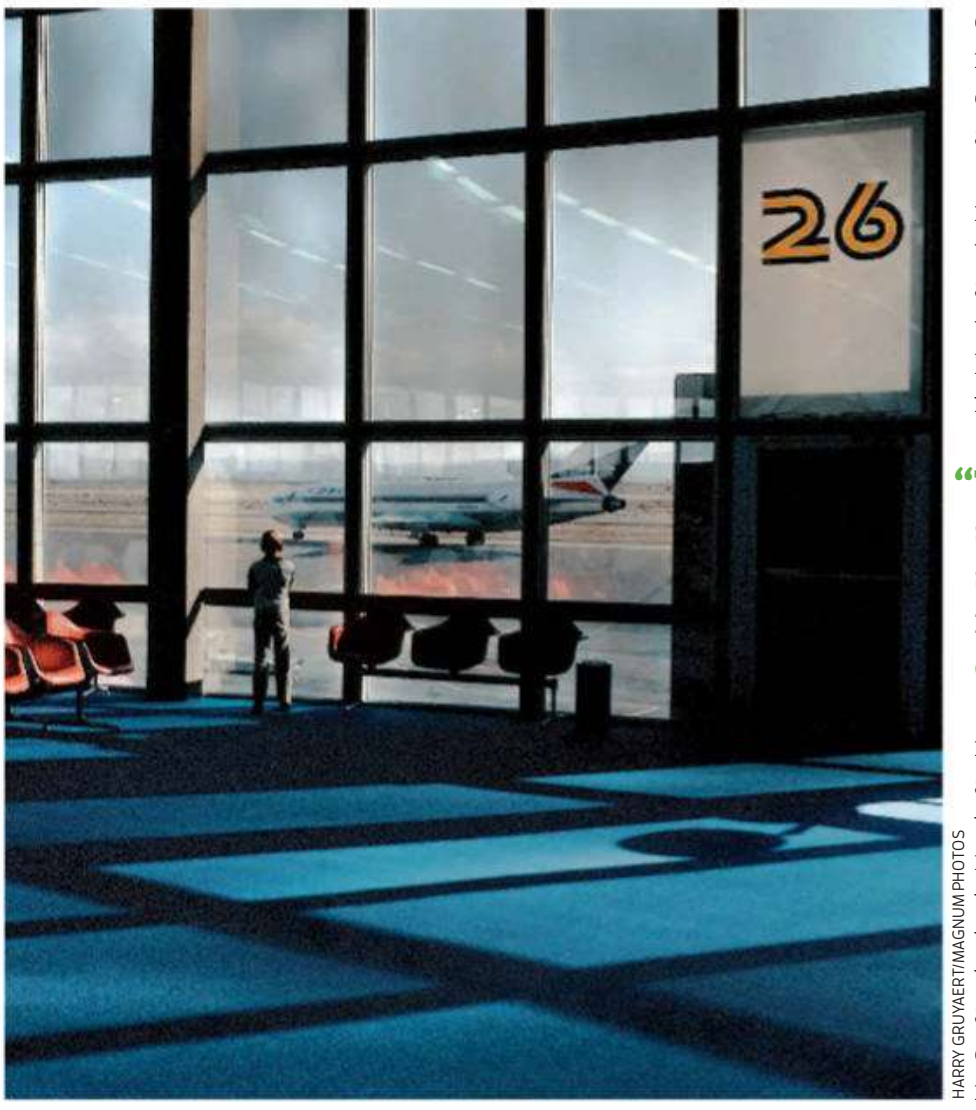
Book
Solitude
Netta Weinstein, Heather Hansen and Thuy-vy T. Nguyen
Cambridge University Press

IN RECENT years, many of us have come to relate differently to the time we spend alone. The globally imposed lockdowns in response to the covid-19 pandemic abruptly curtailed many people's social networks and sources of support. Some struggled and jumped to restart their social lives as soon as restrictions were lifted. But others found they flourished in solitude and never returned to their pre-pandemic levels of socialising.

The sudden shift and range of individual responses highlight something that has long puzzled researchers. Humans not only rely on each other for survival but also take pleasure from social connections. So why do some flail on their own while others thrive?

This is the question posed in *Solitude: The science and power of being alone* by Netta Weinstein, Heather Hansen and Thuy-vy T. Nguyen. Here, they explore questions about, as well as the benefits and challenges of, the hours we spend alone, which account for about a third of an adult's waking life on average.

Even before the pandemic, the hours people spent alone had been steadily increasing for years, with many already working remotely and living alone. These trends have often been reported as evidence of a crisis of connection, but, as the authors point out, some choose this way of living. In fact, individuals have always sought solitude, ranging from anchorites (religious people who withdrew from the world) to explorers setting out on lone expeditions.



HARRY GRUYAERT/MAGNUM PHOTOS

Spending time alone may help us regulate our emotions

Yet today, we may write off that impulse as some sort of pathology.

Clearly it is crucial to distinguish between solitude and loneliness, say the authors. The two may coexist, but they aren't the same, they write, arguing that the "solo self" isn't just compatible with the "social self" but complementary to it, enabling us to relax, recharge and regulate our emotions. So, from admittedly scant research, *Solitude* pieces together a picture of what goes on in our brains and bodies when we are by ourselves.

The dearth of data and the book's subtitle, flagging up the "power of being alone", could have placed it among the softer pop psychology titles, which aim to "reclaim" a stigmatised subject. Refreshingly, however, *Solitude* falls squarely on the side of science, its investigation given heft by the authors' credentials.

Weinstein, who is the director of the European Research Council-funded project Solitude: Alone but Resilient, studies motivation and well-being, whereas Nguyen, who is the principal investigator at the Solitude Lab at Durham University, UK, focuses on the physiology of aloneness and loneliness. With Hansen lending her skills as a science communicator and author, their investigation is grounded, credible and highly readable.

Solitude does well to question the popular narrative of time alone as "something to avoid or endure". In fact, write the authors, it is highly individual, "as empty or full, as certain or uncertain, as we choose to make it".

That the book provokes more questions than it answers underlines the lack of research and our consequent, flawed understandings of loneliness. But perhaps the most surprising finding is that there appears to be

"Throughout history, some have sought solitude, from religious recluses to explorers on lone expeditions"

no correlation between spending and enjoying time alone and the personality trait we label introversion. Being introverted tends to be seen as a bad thing, the mark of a loner or someone who is "antisocial", write the authors, but even people who don't display that personality trait may enjoy spending or choose to spend time by themselves.

With loneliness stemming not from time spent alone but from a sense that social connections are lacking, argue the authors, there is even further emphasis on the need to treat aloneness and loneliness separately. Solitude, it seems, may play an important regulatory role, supporting us as we try to know ourselves separately from our social roles and relationships. It is, say the authors, a new approach to understanding well-being: one not so heavily weighted in favour of our social selves.

True to their scientific cred, *Solitude*'s authors are circumspect about "the power" of solitude. But their first foray into exploring this fundamental experience suggests there will be much more to say. ▮

Elle Hunt is a writer based in Norfolk, UK

Is that a hint of oregano?

Fancy developing sommelier skills? Or making some coffee-infused rum? **Sam Wong** savours a flavourful book

Book
Flavorama
Arielle Johnson
Harvest

WHAT makes roasted meats taste so good? In the 19th century, scientists thought the answer was a mysterious substance known as osmazome, found in the flesh and blood of animals. The influential theorist Jean Anthelme Brillat-Savarin described osmazome as "the most meritorious ingredient of all good soups".

The science of flavour has come a long way. There can be few people better placed to bring us up to speed in 2024 than Arielle Johnson, a flavour scientist who has worked at the celebrated restaurant Noma in Copenhagen, Denmark, and advised top chefs on how to make things delicious. Her book *Flavorama: A guide to unlocking the art and science of flavor* is a comprehensive guide – from how our senses of taste and smell work to the techniques chefs use to create, transform, extract and concentrate flavours.

So, were Brillat-Savarin and his contemporaries onto something with osmazome? They might have been talking about glutamate, a constituent of proteins, identified in 1908 as the trigger for the savoury taste we call umami. But despite the association with "meatiness", most meats have surprisingly little free glutamate, says Johnson, unless they are cured or dry-aged. These processes allow protease enzymes to break down meat proteins over time, leading to the intense umami flavour of meats such as prosciutto. Bacterial enzymes similarly help generate the high levels of glutamate in aged cheeses such as parmesan and roquefort.

What meats do contain in spades are ribonucleotides, another kind of molecule that binds to the umami receptor in a different place to glutamate. When glutamate and ribonucleotides occur together, they have a synergistic effect, creating a much stronger umami sensation than either does alone.

Of course, a large part of the delicious flavour of cooked meat comes from reactions that occur during cooking, notably the Maillard reaction, described by Louis Camille Maillard in 1912. This can occur in any food containing sugars and amino acids, says Johnson, especially at temperatures over 120°C (250°F), and its flavoursome products may also have inspired the concept of osmazome.

Like Elizabeth Zott, the fictional chemist in the novel and TV series *Lessons in Chemistry*, Johnson wants us to become better cooks by understanding the science. But this will only get us so far, she writes. To cook creatively, we need to notice and name what we can taste and smell. Johnson can help here, too: she trains people to be analytical tasters for research studies, and the book explains how to improve your skills. "Palate is 99 per cent paying attention plus practice," she writes.

While our sense of taste responds to five particularly important kinds of chemical in food, we have 400 types of smell receptor that enable us to recognise perhaps as many as a trillion aromas. Johnson shows us how to navigate the vast world of flavour possibilities by thinking of them in groups, such as fruity, herbal, vegetal, spiced and meaty.

Her passion and personality shine through in her writing (and her illustrations), not least in some elaborate metaphors. "Tastes are the foundation and primary structural elements of a stone building like a cathedral," she writes, while "smells are the stained glass – detailed, complex, varied, even narrative." Elsewhere, we learn why terpenes, a family of aroma molecules in herbs and spices, are like the films of Werner Herzog – but no spoilers here.

Johnson also gives us dozens of recipes. Many are simple but revelatory, like coffee-infused rum or smoke-infused oil made with lapsang souchong tea. Others are ambitious: try the vinegar, crème fraiche and pumpkin seed miso. Whatever your skill level, *Flavorama* will help you raise your game. ▮

Copenhagen's Noma restaurant, where researcher and cook Arielle Johnson has worked

THIBAULT SAVARY/AFP VIA GETTY IMAGES

New Scientist *recommends*

Chris Simms
Assistant news editor
London

In **Nye**, Michael Sheen (pictured) brings cheek and vulnerability to the part of Labour firebrand Aneurin "Nye" Bevan, the politician who, in 1948, founded the National Health Service in the UK.

Bevan, decried for speaking out against the wartime strategy of Winston Churchill (Tony Jayawardena is excellent here), gets a slim shot at salvation after being made health minister – and is tasked with the impossible: create a national health service.

Told mainly through hallucinations and recollections, this enlightening, absurdist play may bring a tear to your eye and make you ask why 1940s-style problems seem to have returned. Catch it at the Wales Millennium Centre until 1 June or in cinemas via National Theatre Live.

If you prefer roots to rooting for a politician, try the **Garden Museum** in London or **The Story of Gardening**, an exhibition at The Newt in Somerset, UK. You will discover fascinating tales of people's obsessions with plants and gardens throughout history.

JOHAN PERSSON

The film column

Spinning a web Horror sci-fi *Sting* sees a lonely 12-year-old girl turn a strange spider into a pet that just keeps growing, eventually threatening her family and the neighbours. Think *Alien*, *M3gan* and effortless entertainment, says **Simon Ings**

Simon Ings is a novelist and science writer. Follow him on Instagram at @simon_ings

WELL GO USA ENTERTAINMENT

Charlotte (Alyla Browne) sleeps while her pet spider, Sting, escapes

A BRATTY 12-year-old girl. A feckless stepfather who loses her trust and feels increasingly out of place in his own home. Oh, and a giant spider. Kiah Roache-Turner, a newish director of horror, understands that real originality has almost nothing to do with who and what you put in front of the screen. What matters is how you set those elements dancing.

Like 2023's killer-doll hit *M3gan*, with which it shares a certain antic humour, *Sting* cares about its characters. Charlotte (Alyla Browne) hero-worships her absent father, and this is slowly driving stepdad Ethan (Ryan Corr) up the wall, since he knows her real dad lives only half an hour away "across the bridge". Brooklyn Bridge, New York, that is, where *Sting* is set. The film was, in fact, shot in Sydney, and takes place in a brownstone apartment in Brooklyn, all drywall and ducts.

Ethan is a struggling comic book artist who ends up borrowing (and spoiling) Charlotte's own much livelier ideas. When Charlotte's pet spider (it arrived on a meteor during an ice storm – never a good sign) grows to man-eating size and drags Ethan off through an air duct, Charlotte, plugged into her earphones, her video games and her anger, simply fails to notice.

The scene tries to hit the sweet spot between horror and comedy that *M3gan* struck again and again. If it doesn't quite succeed, it may have less to do with the writing or direction than with the film's premise, which is, when you come down to it, very thin.

"Comparisons with *Alien* are inevitable, if only because of the spider's growth rate and all those ducts"

Comparisons with the original *Alien* are inevitable, if only because of the spider's breakneck growth rate and all those ducts. And as far as the special effects go, Sting the Spider stands up well. Wisely, the film prefers glimpses, shadows and very well-judged sight gags to full-on goo and muppeteering.

The apartment (a realistically over-stuffed gothic interior full of corners and cabinets) is the family in metaphor. Ducts connecting Charlotte's bedroom to the sitting room of her grandmother Helga (Noni Hazlehurst, having more fun than the rest of the cast put together) are the torturous lines of communication by which these good folk struggle to maintain a sense of connection.

The film favours suspense over surprise. We learn early on that Charlotte's pet can't bear the smell of mothballs and that Helga, wrapped in threadbare shawls, stinks of them. For a second, we teeter on the brink of a fairytale in which an old woman and a young girl save the "real" adult world.

Nothing kills a good story faster than cleverness, but a few more touches of that sort wouldn't have hurt. Instead we have an efficient, entertaining, light-hearted script, very ably realised, and one and a half hours of light entertainment that, though not at all wasted, aren't filled to the brim, either.

Why, then, has *Sting* acquired global distribution and, before its release, such glowing trade coverage? Well, for one thing, it is refreshing to see a movie that puts its characters through the wringer in psychologically believable ways. Charlotte saves Ethan. Ethan saves Charlotte. In the face of a fate worse than death (trust me here), the two learn to cooperate. A weak man gains strength, a lonely child learns that there is value in other people, a cowardly exterminator loses his head and a bitter landlady plummets down a lift shaft. What's not to like?

Storytelling this pure looks effortless, but if it were, films in general would be a lot better than they are. ▮

Film
Sting
Kiah Roache-Turner
In cinemas (US); Releasing 31 May (UK)

Simon also recommends...

Book
Web
John Wyndham
Published 10 years after his death, Wyndham's sly last novel takes a utopian colony to an uninhabited Pacific island that turns out to be irradiated and infested with tiny, talented spiders.

Film
Coraline
Henry Selick
Laika
This utterly traumatising animation shows how far into the weird you can go armed with a talking cat and a box of buttons.

Editor's pick

Offsetting can still be done, but it costs a lot

11 May, p 22

From Pete Drake, Penmon, Anglesey, UK

Graham Lawton can count me as a staunch fan. I agree with him that it is self-deception to imagine that he offset much, if anything, of his flight-related carbon dioxide by crossing a greenwashing scheme with a tiny piece of silver. This doesn't mean it is impossible.

I fly perhaps once a year, for family reasons, and pay for my carbon to be removed via biochar. This costs a lot, almost exactly the same as my long-haul airline ticket. It also comes with reliable, accredited certification.

If we, the affluent-enough-to-go-on-CO_2-belching-jollies, actually cleared up our pollution, the planet would be back several decades into the last century, pollution-wise, and mother nature would have hope and a reasonable chance.

From Dyane Silvester, Arnside, Cumbria, UK

Has Lawton considered that his carbon offset certificate's "1.69 mt" might actually be a correct use of the prefix "m" and mean that he has paid to offset 1.69 millitonnes of carbon? He could probably do a better thing for the environment if, instead of paying into a rather opaque "carbon offset" market, he visited his local garden centre and bought a native tree to plant at home, or for a nature reserve if lacking space to do so at home.

Fall of civilisations may have been germ warfare

11 May, p 32

From Philip Norrie, Sydney, Australia

You report the end of the Bronze Age in the eastern Mediterranean 3200 years ago has generally been characterised by its short duration of 50 years, mass migration of populations such as the Sea Peoples and abandonment of cities. In my view, the Sea Peoples were pushed out of their homes by plague etc. The events have all the trappings of an infectious disease pandemic, an idea I focused on in my 2014 university thesis.

When it comes to such upheavals, may I suggest we factor in the possibility of some form of infectious disease being involved as a "wild card" game changer.

The Anthropocene: it is less about the dates

11 May, p 21

From Matthew Edgeworth, Bedford, UK

Jan Zalasiewicz implies that the mass of evidence of human impact on the Earth system was rejected in the recent vote by geologists over the Anthropocene. Actually, few scientists would dispute that substantial body of evidence. What was rejected was the specific proposal that the start of the Anthropocene epoch should be placed in 1950 or 1952.

We are in the Anthropocene for sure, and human influence on planetary change is all too real. It is time to stop thinking narrowly of the Anthropocene as a time interval and instead focus on the many manifestations of the material Anthropocene event unfolding all about us.

I have modernised my relationship with cancer

27 April, p 21

Name and address supplied

Thank you for David Ropeik's excellent and, for me, timely article on cancerphobia. I have just undergone treatment for breast cancer, including surgery and radiotherapy. I have deliberately limited the people who know, specifically because I couldn't face inaccurate, exaggerated, even hysterical responses. I am still working out how I might broach the subject; most probably, I won't.

A calmer world may not be a good thing

11 May, p 14

From Geoff Harding, Sydney, Australia

In your look at whether climate change is accelerating after a record year of heat, you cite models that predict a speeding up due to underestimates of the loss of the cooling effect of some pollutants. These are in decline as clean air policies take hold.

The contribution of wind doesn't seem to have been fully accounted for either. The IPCC predicts that as the planet warms, average wind speeds will fall due to lower temperature gradients. Lower wind speeds have possibly contributed to the recent record high ocean temperatures, because of a reduction in the cooling of the waters due to wind-induced evaporation. Slower winds also result in lower infrared emissivity of the ocean surface, which would reduce heat loss by radiation.

Remembering when maths meets real life

27 April, p 44

From Keith Walters, Sydney, Australia

Katie Steckles's article about "Pythagoras in the wild" reminds me of an interesting experience of encountering maths when buying cake tins. I got two "catering-sized" square ones from a commercial baking supplier. I was intrigued by the dimensions: about 360 millimetres per side. That figure didn't seem to mean anything special. Neither did the equivalent 14.14 inches.

Then light dawned! 14.14 is the square root of 200, so those tins give you 200 square inches of cake, and, assuming a 1 inch by 2 inch serving, that comes to exactly 100 servings. Ideal for the "nothing left to chance" caterer!

Population decline will put us on slippery slope

Letters, 20 April

From Hubert van Hecke, Santa Fe, New Mexico, US

Several readers have voiced optimism about reaching a new economic equilibrium in a world where each generation is smaller than the previous one.

However, such an equilibrium would be only temporary. Once the world population falls to, say, half a billion, no one is building a new particle collider or flying to the moon. And in a world with 100 million people, can I even buy a refrigerator? I don't think so.

The current epoch, for better or worse, may be "peak humanity", not just numerically speaking.

To escape light pollution, try life on the ocean waves

4 May, p 22

From Butch Dalrymple Smith, La Ciotat, France

Chanda Prescod-Weinstein laments the difficulty of seeing the night sky due to modern lighting. There is one group of people who can still appreciate it with no problem: sailors.

On the ocean in a sailing yacht you experience the heavens at full brilliance in a sky devoid of light, chemical or smoke pollution. No wonder sailors tend to be poetic and philosophical. When I spent much of my time sailing, I had a strong affinity with the stars.

Want to get in touch?

Send letters to letters@newscientist.com; see terms at newscientist.com/letters

Letters sent to New Scientist, 9 Derry Street, London, W8 5HY will be delayed

For the record

Christopher Stiles is at the Johns Hopkins Applied Physics Laboratory (11 May, p 40).

How to think about...

SCIENCE is our best route to understanding an otherwise unfathomable universe. And yet the path to enlightenment is far from straight and smooth. It throws up all manner of concepts to help us make sense of things that can appear to not make much sense at all – and then chucks in a bunch of fresh discoveries that force us to reconsider those concepts. That's what makes it so much fun. But even for the curious and well-informed, it can be hard to get to grips with some of the most nebulous, controversial and mind-boggling ideas.

Which is why, over the next 11 pages, we are going to clear a few things up by asking the experts how they think about 12 of the trickiest concepts in science and technology, from neurodiversity and fractals to artificial general intelligence and quantum biology – and even thought itself.

STEPAN POPOV/STOCK.ADOBE

THOUGHT

WE'RE ALL AT IT, all the time. Yet thinking, or how we should think about thought, is surprisingly hard to pin down. When I did a vox pop, for instance, a couple of friends described thoughts as "wispy things". Another saw them as sparklers, fizzing with chaotic flashes but containing a central light source that is controllable.

All of which is decidedly unscientific. But then even the experts aren't so sure about what thoughts are, and what we can surmise from the latest neuroimaging studies suggests we may never truly pin down how they manifest in the brain.

"The short answer is that no one really knows what thought is," says Tim Bayne, a philosopher at Monash University in Australia and author of *Thought: A very short introduction*. Even so, it is useful to consider two aspects of thought, he says: their content and their nature.

Kalina Christoff's definition does exactly that. "Thought is a mental state, or series of mental states, that has some kind of content to it, with some personal attitudes towards the content – like an attitude of remembering or believing or imagining," says Christoff, who runs the Cognitive Neuroscience of Thought Laboratory at the University of British Columbia in Canada.

First, let's consider content. Thinking isn't the same as perceiving or sensing: all involve holding something before one's mind, so to speak, but thoughts are distinct in that they are independent of any stimulus produced by the thing being thought about.

In terms of how they arise, Christoff identifies three streams that feed into our consciousness to instigate thoughts: exteroceptive (from the outside world), interoceptive (from your organs and internal physiological environment) and conceptive (a term she uses to describe input that "wells up" from the subconscious in the form of spontaneous thought, including mind wandering or daydreaming, as opposed to intentional thought such as reasoning and problem-solving).

Within content, there is form. There are five main kinds of thought, according to Russell Hurlburt at the University of Nevada, Las Vegas, who invented "thought sampling", in which volunteers record their current inner experience when prompted randomly by a beeper. This process reveals that a thought can be verbal, visual, emotional, founded in bodily sensations or unsymbolised (none of the above, yet still distinct) – or a mixture of these. There is enormous variation between individuals in terms of how they think, says Hurlburt, even if many of us fail to recognise this (see "Neurodiversity", page 39).

As for the nature of thought, or what thoughts look like in the brain, Christoff uses functional magnetic resonance imaging to explore this. "For sure there are neural correlates," she says. Some of the brain activity simply reflects the kind of thought being had – for example, a visual thought will show activation in the visual cortex. More surprising is what happens prior to spontaneous thought: about 3 seconds beforehand, there is activity in parts of the default mode network, which generally fires up when your brain is idling, and also in brain regions associated with memory. The latter have unusually diverse connections, which might help explain why spontaneous thoughts are so eclectic and arbitrary.

> "WE MAY NEVER TRULY PIN DOWN HOW THOUGHTS MANIFEST IN THE BRAIN"

Neuroimaging can give us a general idea of what someone is thinking, then. But Christoff doesn't believe it will ever accurately interpret the subjective experience of thinking and thus make it possible to read people's minds – something that has been touted as a goal for the brain-computer interfaces being pursued by Elon Musk's Neuralink, among other companies. "The mind emerges out of a physical substrate, the brain, and the relationship of emergence is not deterministic," she says.

Kate Douglas

ROGUE PLANETS

IMAGINE A WORLD where it is always night, no matter the time of day or year. There are no days or years, in fact, because there is no sun, meaning no cycle of daylight to mark time's passing. And if there are moons, they are barely visible. For this is a lonely world, drifting through interstellar space.

Rogue planets, as they are known, do exist – and there are probably a lot of them. They could outnumber stars by up to 20 times, according to a 2023 analysis by David Bennett at NASA's Goddard Space Flight Center in Maryland and his colleagues, which would mean there are possibly trillions of them in our galaxy alone.

That might sound like an outlandishly large number, given that we tend to think of planets orbiting stars. But the existence of free-floating planets is perfectly compatible with planetary formation theory. "Honestly, I was not surprised to find that rogue planets may outnumber stars," says Gavin Coleman at Queen Mary University of London.

Which isn't to say astronomers aren't awestruck by the prospect. "It's beautiful to imagine," says Lisa Kaltenegger at Cornell University in Ithaca, New York. "Billions of planets that have no home any more, that are just basically travelling through the galaxy."

We can't see rogue planets directly. Since the first candidate was discovered in 2012, we have been inferring their presence by the way they bend the light coming from more distant stars and galaxies, known as gravitational microlensing. From this, it appears as if most rogue planets are around the size of Earth.

Those that are larger could start life in a similar way to a star, with clouds of gas gathering under gravity and eventually collapsing. But this can't account for Earth-sized rogue planets, says Coleman – those must have formed within a solar system and then been ejected. An outside star might have swept by, tugging on the planet as it went, but this is only likely in star-dense regions of the galaxy, like globular clusters. Another option is that a tussle with another planet in the system flung one closer to the star and one away, out into the wilds.

The most likely explanation for rogue planets in the Milky Way is that they formed around pairs of stars orbiting each other, called binary systems. "In binary systems, it is very easy for planets to be placed on orbits that eventually lead to their ejection," says Coleman.

As for the conditions on rogue planets, we can expect the same rich diversity we see in star-bound planets – from smaller rocky worlds to massive gas giants like Jupiter and icy exoplanets bigger than Neptune. "I imagine that rogue planets will be very similar to a lot of these," says Coleman. Except for the fact that, with no host star for light, the only source of warmth will have to come from within. As such, it is likely that rogue planets will have frozen surfaces.

> "THERE COULD BE TRILLIONS OF THESE LONELY WORLDS IN OUR GALAXY ALONE"

One source of energy could come from thermal vents powered by the contraction of the entire planet as it cools down, the mechanism that leads to cryovolcanism on Pluto. But there are ways such a rogue planet could be warmer than this. David Stevenson at the California Institute of Technology, Pasadena, has argued that if they had large amounts of hydrogen in their atmospheres, which is a greenhouse gas at high pressures, rogue planets could even have surface temperatures similar to those on Earth. "Such a planet could be kept warm by the radioactive decays of elements deep in its interior," says Bennett.

Simulations have even suggested that some rogue planets might have what it takes to be habitable, either in liquid oceans beneath their icy outer crusts or on the surface if they can sustain a thick hydrogen atmosphere to trap enough heat to sustain life.

Abigail Beall

think about...How to think about...How to

SHUTTERSTOCK/ARTSIOMP

Rogue planets are likely to be frozen worlds

SUNNY/GETTY IMAGES

Dropping the cup leads to it smashing – or does it?

CAUSALITY

YOU DROP A CUP and it smashes. I flick a light switch and the bulb glows. Effect follows cause – it is a hard-and-fast rule of the universe. Except, perhaps, at a fundamental level. Because when we are dealing with the electrons behind the working of the light switch and the atoms in the bulb that convert electrical energy to light, causality appears to be a lot fuzzier.

In 2017, a team at the University of Vienna in Austria described an experiment demonstrating that, in the quantum realm of atoms and particles, it is impossible to say which observations were the effect and which were the cause. It was, in the words of the researchers who did the experiment, "the first decisive demonstration of a process with an indefinite causal order".

> "TO FIGURE OUT QUANTUM GRAVITY, CONVENTIONAL NOTIONS OF FIXED TIME AND CAUSALITY MUST GO"

And yet the wider research community didn't drop their coffee mugs. On the contrary, it was welcome news for at least some of those seeking to figure out where space-time comes from. For them, a quantum theory of gravity, in which space-time would be an emergent property of more fundamental constituents of the universe, might necessarily lack the definite one-way causality of everyday life.

Space-time, as described by Albert Einstein's theories of relativity, already has some fuzziness when it comes to defining the order of events. People moving through space and time in different ways have different "reference frames", and those moving in different ways won't always agree on whether event A happened before event B.

This doesn't allow breaches of causality, though. The blurring of before and after happens only over distances so large that those regions of space can't affect each other because of the limit on the speed of light. "If one event could send a light signal to the other, then there is no reference frame in which you could confuse their order," says Giulia Rubino, now at the University of Bristol, UK, who led the 2017 work.

However, "indefinite causality" is possible in the minuscule quantum world because the rules that govern the behaviour of atoms, electrons and photons of light permit a phenomenon called "superposition". This is where a system of such entities can exist in two or more states simultaneously – even if common sense would say that it is impossible for those states to co-exist. Thus the 2017 experiment involves creating a superposition of "A causes B" and "B causes A" when dealing with photons, or particles of light, that are themselves in superposition.

That isn't discombobulating for physicists because the fundamental laws of quantum physics don't specify a direction for time, says Huw Price at the University of Cambridge: "Physics doesn't care about the difference between past and future."

Hence, there is scope for "time-reversal symmetry", where particles behave in the same way if you make time run in the opposite direction. Nor do physicists rule out the possibility of backwards causation, or "retrocausality", in which a light bulb's glow could cause its switch to turn on.

The reason why some theorists embrace indefinite causality is that if space-time is fundamentally quantum mechanical – as many think it must be – then gravity must somehow be quantum mechanical too. To figure out what this quantum gravity looks like, Lucien Hardy at the Perimeter Institute for Theoretical Physics in Waterloo, Canada, has suggested combining the characteristic features of general relativity and quantum mechanics: the malleability of space and time and superpositions of simultaneous possibilities, respectively. If you do that, he reasons, conventional notions of fixed time and causality must go.

"It seems that some situations, such as indefinite causal order, should be natural in quantum gravity," says Caslav Brukner at the Institute for Quantum Optics and Quantum Information in Vienna.

Michael Brooks

BIODIVERSITY

AT FIRST BLUSH, the idea of biodiversity seems simple enough. It is essentially the variety of all life on Earth. But making sense of biodiversity in a way that can help us halt or even reverse its decline is anything but straightforward.

"People often use the word biodiversity just to mean any characteristic of life out there that we might care to protect," says Mark Vellend, a biologist at the University of Sherbrooke in Quebec, Canada. "That's not a definition I find useful in science because if it's everything, it's nothing."

For biodiversity to be a valuable concept, he says, it needs to be a measure of biological variety. That way, we can not only assess where we are and where we are headed, but also how best to conserve the biodiversity we have left.

The problem is that variety itself comes in many forms, especially in biology. "You can't just come up with a single number for biodiversity in the same way as you can for carbon," says Andy Hector at the University of Oxford. "It's way, way more complicated."

We already have ways to measure biodiversity. That's how we know it is in steep decline. They boil down to what biologists think of as dimensions of biodiversity. One of the most basic is species richness, which is simply the number of species in a given place at a given time. This has been used extensively and can sometimes be a useful proxy for other dimensions of biodiversity, says Hector.

One of those is the relative abundance of the different species. Two ecosystems can be equally rich in species, but not in diversity. "The way I like to explain it is if you walk through a forest or swim through a coral reef and you see two organisms in sequence, what are the odds that they're going to be different things?" says Vellend. "You could have a thousand types of things in there, but if 99 per cent of them are of one type, then the odds are, when you see two in a row, it's going to be the same thing."

A third dimension is how different the species are from one another in some important aspect. "Functional diversity", for example, looks at the range of different roles that species play in an ecosystem, such as in photosynthesis, nutrient recycling, predation or pollination.

But there is also a fourth dimension, which tracks how the other three change over time. Every measure of biodiversity worth its salt captures one or more of these aspects, weighted according to what data is available and the project's goals. "It all depends what you want," says Hector. "Are you trying to conserve biodiversity for biodiversity's sake or is it more human-centric?"

> "YOU CAN'T JUST COME UP WITH A SINGLE NUMBER FOR BIODIVERSITY IN THE SAME WAY AS YOU CAN FOR CARBON"

And here's where things get knotty, because there are myriad ways of measuring each dimension. That means the whole thing risks becoming frighteningly fractal (see "Fractals", page 39) – and indeed fractious. When discussions started on how to define the 2020 global biodiversity targets, there were nearly 100 suggestions on the table, according to Henrique Pereira at the University of Halle-Wittenberg in Germany.

In 2013, researchers led by Pereira began trying to standardise the way biodiversity is measured. They distilled biodiversity to six key dimensions: genetic composition, species distribution and abundance, species traits, community composition, ecosystem functioning and ecosystem structure. These capture the essence of biodiversity and how it is changing in a format that biologists can measure and share, says Pereira.

Not everyone is on board. But there is at least a growing realisation that the time for such quibbling has long passed. There isn't, and probably never will be, a comprehensive measure of biodiversity, says Hector. And ultimately, "we don't have the luxury of waiting until all life is documented", he says.

Graham Lawton

HANS-JOACHIM SCHNEIDER/ALAMY

Biodiversity contains several dimensions

QUANTUM BIOLOGY

"I'M NOT SAYING it's all true," says Christoph Simon, a physicist at the University of Calgary in Canada. "I'm just saying it is not crazy to look for it." He is talking about the possibility that life has found ways to make use of quantum effects in a host of essential phenomena, from photosynthesis and the navigational abilities of birds to consciousness.

The idea has long been seen as a bit fringe, on the assumption that such fragile effects must quickly disappear in the warm, wet environment of cells. Quantumness tends to prosper in very cold systems that are carefully isolated rather than part of a tepid soup awash with other activity.

But that is beginning to change, with tentative evidence for quantum behaviours in the machinery of cells and hints that quantum biology may not play by the conventional rules governing the subatomic world, raising new questions about the boundary between the classical and quantum realms.

"You could say, 'well, all molecules are quantum mechanical, so everything in biology is quantum mechanical'," says Greg Scholes, a chemist at Princeton University. But the idea of quantum biology only really gets interesting, he says, with the possibility that it explains emergent macroscopic behaviour that can't be predicted using classical laws.

Finding such behaviour typically means searching for evidence of archetypal quantum traits such as superposition, in which a system appears to exist in multiple states simultaneously before it loses this so-called quantum coherence and "collapses" into one state or another – a process called decoherence.

Hints of superposition have been observed in proteins called microtubules in cells in vitro, for example, but so far all these results are only "correlative", says Clarice Aiello, who leads the Quantum Biology Tech (QuBiT) Lab at the University of California, Los Angeles. That is because we haven't pinpointed how microscopic quantum behaviour might produce macroscopic consequences. "No one has unambiguously proven or refuted whether quantumness survives inside cells for long enough for it to matter," says Aiello.

She has a few ideas about how that might happen, though. Her research focuses on the surprising effect that magnetic fields have on a host of biological processes – from cell metabolism to DNA repair. "The whole machinery of cells might be responding to weak magnetic fields," she says. The idea is that these fields influence a quantum property of electrons called spin, which is relatively resilient to loss of quantumness, with knock-on effects for the chemical products that form downstream in biochemical processes. "The macroscopic consequences would be felt for much longer than the quantumness," says Aiello.

Scholes, meanwhile, is building a new theoretical framework to tell us where – and how – to look for quantum effects in biology. His take-home message is that the usual quantum rule book, based on interactions between small numbers of particles, doesn't apply. "We need to embrace [quantum biology's] complexity," he says. "Somehow, we need to develop a new kind of language."

Broadly, coherence is characterised by the extent to which different waves are in step with each other, known as their phase, so Scholes began to look for an equivalent in biology. He borrows the mathematics of graph theory, which describes the relations between large numbers of objects, adding up biological oscillations to identify an emerging pattern of phases. Scholes says that oscillations occur in living organisms, including in biochemical process inside cells and across networks of neurons in the brain. He suggests they could be behind some of the hints of quantum effects seen in experiments.

Scholes's ideas have also begun to blur the boundary between what we think of as quantum and classical. Although these biological states are akin to quantum superposition, all of his calculations were done using classical laws of nature. For this reason, Scholes calls them "quantum-like" states.

He has even started to speculate about what these quantum-like states might be doing inside brains: "They could bring information from different regions together quickly and efficiently, to give a leap of intuition, or a moment of recognition."

Thomas Lewton

t...How

to think about...How

AGI

IF YOU TAKE EVEN a passing interest in artificial intelligence, you will inevitably have come across the notion of artificial general intelligence. AGI, as it is often known, has ascended to buzzword status over the past few years as AI has exploded into the public consciousness on the back of the success of large language models (LLMs), a form of AI that powers chatbots such as ChatGPT.

That is largely because AGI has become a lodestar for the companies at the vanguard of this type of technology. ChatGPT creator OpenAI, for example, states that its mission is "to ensure that artificial general intelligence benefits all of humanity". Governments, too, have become obsessed with the opportunities ›

AGI might present, as well as possible existential threats, while the media (including this magazine, naturally) report on claims that we have already seen "sparks of AGI" in LLM systems.

Despite all this, it isn't always clear what AGI really means. Indeed, that is the subject of heated debate in the AI community, with some insisting it is a useful goal and others that it is a meaningless figment that betrays a misunderstanding of the nature of intelligence – and our prospects for replicating it in machines. "It's not really a scientific concept," says Melanie Mitchell at the Santa Fe Institute in New Mexico.

Artificial human-like intelligence and superintelligent AI have been staples of science fiction for centuries. But the term AGI took off around 20 years ago when it was used by the computer scientist Ben Goertzel and Shane Legg, cofounder of the AI firm DeepMind. The phrase neatly encapsulated the growing sense that the field should move beyond narrow applications to build systems that can do everything a human can do.

Since then, DeepMind in particular has sought to redefine AGI such that it pertains only to "cognitive tasks". Last year, Legg, together with DeepMind cofounder Demis Hassabis and their colleagues, elaborated on what constitutes an AGI. They proposed a six-level framework, where the top level is a system that can "outperform 100 per cent of humans" across a "wide range of non-physical tasks, including metacognitive abilities like learning new skills".

"The levels idea is really pointing out that there's this continuum," says team member Meredith Morris at DeepMind, now part of Google. "There's this progression as technology evolves." Morris hopes their work will draw more attention to the idea, and ultimately to some form of consensus on what AGI actually is: "We would love to have folks from those other fields that study intelligence and learning working together with our researchers on developing these benchmarks."

But Mitchell points out that intelligence is itself a multidimensional concept, with a lot of crossovers with other equally murky concepts, such as sentience and understanding. As such, it isn't readily measurable with a test in the same way as other, more concrete tasks, like the ability to translate language.

Applying more scrutiny to when an AI could be considered an AGI might yield progress, but Mitchell is still sceptical that the sort of machine that AGI proponents envisage will be achieved, because it is unclear whether the faculties of human intelligence can ever be abstracted into standalone concepts – never mind replicated in AI. "There's a kind of faith that the field has had for a long time, that we can develop human-level intelligence in these disembodied substrates," she says. "Whether that's possible or not, I think it's a big open question."

> "SOME ARGUE THAT AGI IS A MEANINGLESS FIGMENT THAT BETRAYS A MISUNDERSTANDING OF THE NATURE OF INTELLIGENCE"

For Thomas Dietterich at Oregon State University, the problem with AGI is a more practical one – namely that it is a mistake to define artificial intelligence with respect to humans. "We have this focus on replicating our capabilities, and this leads to the rampant anthropomorphisation of our systems, giving them names like Siri and Alexa."

Instead, he says, we should think of AI as "an intelligence prosthetic that can do certain things for us" – which sounds a lot like what the AI community had in mind before the concept of AGI came along.

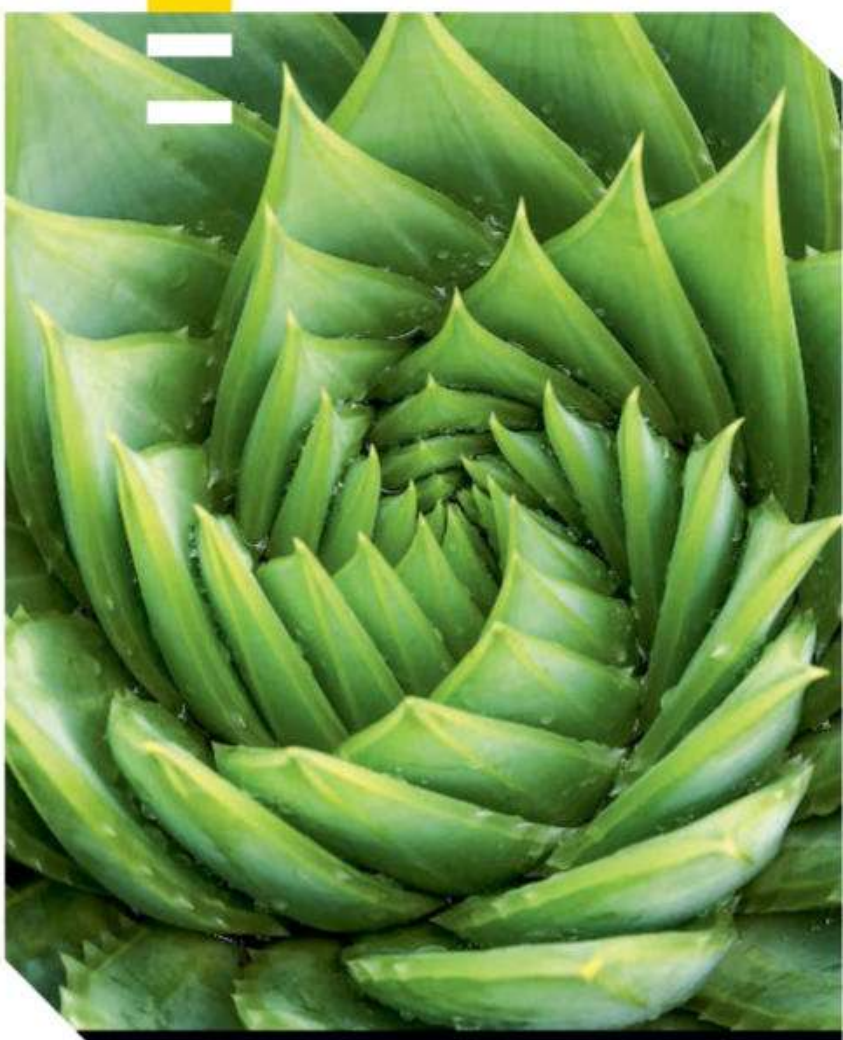
Alex Wilkins

to think

YOU HAVE ALMOST certainly seen computer-generated fractals – beautiful, trippy images in which colourful, intricate structures repeat ad infinitum as you fall ever further down the rabbit hole. Formally speaking, fractals are infinitely complex patterns that are self-similar across different scales. But, in an echo of their geometry, fractals can help us better understand the world on many levels.

Let's start with the familiar: fractals in nature. "They are all around us – in trees, mountain ranges, river deltas and so on," says Dave Feldman at the College of the Atlantic in Bar Harbour, Maine. Such ubiquity makes sense because of the way fractals are made:

Fractal geometry is common in nature



SHUTTERSTOCK/SABINE HORTEBUSCH

FRACTALS

"a simple iterative process – repeated folding or branching – can produce fractals", he says.

These forms aren't just for gawping at, though. The inside of your lungs is fractal for a reason: such arrangements cram a huge surface area into a small volume of space. This is how evolution solved the problem of maximising the area of tissue that can absorb oxygen.

Where fractals get baffling, however, is in the reasons they captivate mathematicians, not least as a playground for exploring numbers. This is where we encounter fractal dimensions. In our everyday world, a straight line is one-dimensional, a square or rectangle two-dimensional and a cube or sphere three-dimensional. But fractal structures have dimensions in between these values. Though largely impossible to visualise, you can think of these as a measure of how much complexity a fractal contains – or how many self-similar structures you can break it into at a given magnification.

These kinds of measures can matter. As a coastline changes over time, so too does its fractal dimension, which can give a measure of the effect of sea level rise, while the fractal properties revealed by MRI scans can help doctors diagnose various diseases. "Lung disease is often a disturbance in the fractal complexity of the lungs, and Alzheimer's degrades the fractal complexity of neurons," says Peggy Beauregard at Hartford University in Connecticut.

Fractals also help us make sense of weather, climate and other "chaotic" systems – those that develop along wildly different paths through a map of all their possible states in response to the tiniest change in initial conditions. The connection with fractals is that the map of these paths, known as an "attractor", often has a fractal structure.

Hidden fractal structures might even transform our understanding of fundamental physics, according to Tim Palmer at the University of Oxford. He has developed a way of describing the laws of physics in terms of fractal geometry, where all the possible states of the universe are represented by an attractor, an arrangement that precludes some states from ever being reachable.

That would explain away the weirdness of quantum "entanglement", says Palmer, where two or more particles affect each other in ways that defy common sense (see "Quantum entanglement", page 41). He says entanglement is an illusion created by imagining that the universe can move between any and all possible states, when in reality it can't.

But Palmer goes further, proposing that rethinking all of physics based on fractal geometry could show how the small and large-scale properties of the universe are interconnected (see "Scale", page 43). "The laws of physics are much more holistic than we think," he says.

MB

NEURO-DIVERSITY

AS A CHILD, I was frequently scolded for zoning out in class, interrupting conversations and losing just about everything I owned. It wasn't until adulthood, when I was diagnosed with ADHD, that these "bad habits" began to make sense.

The idea that my brain is wired differently is the foundation of neurodiversity, a relatively new framework for understanding neurodevelopmental conditions like ADHD and autism. "Neurodiversity reflects an awareness that, across humanity, we have many different ways of perceiving and relating to the world that reflect differences in our brain development and brain function," says Geraldine Dawson at Duke University in North Carolina.

Instead of viewing these differences as problems to be fixed, a neurodiverse approach aims to embrace them, she says.

That seems clear enough. But the concept of neurodiversity has been a source of debate in recent years, particularly in terms of what it means for psychiatrists and neuroscientists, who have long thought in terms of neurodevelopmental "disorders", and the people they are seeking to help.

"Some people take it that the neurodiversity paradigm is against the medical paradigm," says Anita Thapar, a psychiatrist at Cardiff University in the UK. "What I have argued in several papers is that both are useful for difference purposes."

To start from the beginning, the term "neurodiverse" was first coined in the late 1990s by sociologist Judy Singer, who used it when describing ›

people with autism who had no intellectual impairments but struggled with relating to others or had repetitive behaviours.

The idea was to view autism as a difference, rather than as a disease or disorder, says Thapar. It also emphasised the many strengths that can come with autism, such as high levels of creativity, an intense focus on special interests or out-of-the-box thinking.

And it seems to have brought positive outcomes, by encouraging people to view their condition in a more positive light. Research shows, for example, that taking a strengths-based approach to autism improves social engagement, learning and self-advocacy and reduces anxiety.

"The strengths-based model is not about solving all problems, it is about helping people on the [autism] spectrum so that they are going to be able to have opportunities just like everyone else," says Lawrence Fung at Stanford University in California.

BJANKA KADIC/ALAMY

Which brings us to a key point, and one that is commonly misunderstood – namely that neurodiversity isn't meant to minimise the fact that autism comes with real challenges, says Dawson. Rather, it focuses on reducing those difficulties with interventions that allow for agency and choice, she says.

Over the years, the concept has expanded to encompass the entire autism spectrum, as well as other neurodevelopmental conditions like ADHD, learning disabilities and dyslexia. Some have taken it even further, suggesting that people with mental health conditions like anxiety, depression and schizophrenia are also neurodiverse – or even that we are all neurodiverse, in the sense that no two brains are the same.

This is where the waters get muddy. "From a research perspective, we have never been able to draw a firm line between what is neurotypical and what is neurodiverse," says Dawson. But that presents a problem, says Thapar. "I think to call everything neurodiverse becomes meaningless."

For her, "neurodiverse generally means those with early neurological brain differences". In other words, neurodevelopmental conditions. And Thapar is clear that embracing neurodiversity needn't mean abandoning diagnosis and intervention altogether. The trick is to pay attention to the extent to which a person's neurodevelopmental difference is causing them problems, as well as their wants.

"You need to have that flexibility," she says. "When I'm seeing someone in clinic, I'm not just thinking about their brain, I'm thinking about them. I'm thinking about them as a person."

Grace Wade

> "EMBRACING NEURODIVERSITY NEEDN'T MEAN ABANDONING DIAGNOSIS AND INTERVENTION"

NET ZERO

A DECADE AGO, the term "net zero" was arcane jargon. Today, it is the key goal of the fight against climate change and a familiar talking point across the world.

The concept is straightforward. In the words of the Intergovernmental Panel on Climate Change (IPCC): "Net zero carbon dioxide (CO_2) emissions are achieved when anthropogenic CO2 emissions are balanced globally by anthropogenic CO_2 removals over a specified period."

It is also easy to trace the concept's rise to prominence. Once the need for net-zero emissions to halt rising temperatures was established, it made its policy debut in the 2015 Paris Agreement. It then exploded into public consciousness following a 2018 IPCC report explicitly stating that the world must reach net zero by 2050 to avoid the worst effects of global warming. The UK soon became the first major economy to come up with a net-zero emissions pledge. Now, most countries, including China, the US and India – the three largest emitters – have made such pledges of some sort.

What is less clear, however, is whether all these targets are strong enough to get us to net zero fast enough – and what happens to the climate once we do reach our goal.

Many net-zero pledges are "poor", according to the Climate Action Tracker project. Often countries' plans lack achievable interim steps or leave out important sectors of the economy. That suggests most deadlines will be missed. But reaching net zero 50 years from now, for instance, isn't enough, says Amanda Levin at the Natural Resources Defense Council. "You have to make efforts to cut carbon today."

What's more, achieving net-zero emissions is just one of several important goalposts on which the future climate depends. How much we emit before reaching net zero and what happens after we get there are equally important, says Levin.

Another issue lies in how emitters can claim to be making progress by paying for others to avoid emissions – for instance by protecting a forest that would otherwise be cut down – rather than reducing their emissions. While such "carbon offsets" work in theory, in practice they are often difficult to verify, says Levin. "The offset market today is highly unregulated and, honestly, a Wild West."

Besides, offsetting based on avoided emissions will grow ever scarcer as we run out of emissions to avoid, so it can't be part of the long-term solution, says Myles Allen at the University of Oxford. "Because it's been abused, the environmental community is now fed up with it." As a result, some have called for commitments to "real zero," as in no emissions whatsoever. But emissions from long-distance flights or fertiliser use, for instance, are nigh-on impossible to eliminate, says Levin. Hence the push for CO_2 removal through technologies like direct air capture or other, nature-based approaches.

As for what will happen if the world does reach net-zero emissions on time, one recent study found that warming feedbacks could mean temperatures continue rising, depending on how much we emit overall. In that case, even more carbon removals would be needed to both address the overshoot and maintain net zero as natural sinks begin to bring down the atmospheric concentration of CO_2. "The real balance we need in the long term is between producing carbon dioxide and permanently disposing of it," says Allen.

James Dinneen

QUANTUM ENTANGLEMENT

WHILE SCIENTISTS generally try to find sensible explanations for weird phenomena, quantum entanglement has them tied in knots.

This link between subatomic particles, in which they appear to instantly influence one another no matter how far apart, defies our understanding of space and time. It famously confounded Albert Einstein, who dubbed it "spooky action at a distance". And it continues to be a source of mystery today. "These quantum correlations seem to appear somehow from outside space-time, in the sense that there is no story in space and time that explains them," says Nicolas Gisin at the University of Geneva, Switzerland.

But the truth is that, as physicists have come to accept the mysterious nature of entanglement and are using it to develop new technologies, they are doubtful that it has anything left to tell us about how the universe works.

You can create quantum entanglement between particles by bringing them close together so that they interact and their properties become intertwined. Alternatively, entangled particles can be created together in a process such as photon emission or the spontaneous breakup of a single particle such as a Higgs boson.

The spooky thing is that, in the right conditions, if you then send these particles to opposite sides of the universe, performing a measurement on one will instantaneously affect the outcome of a measurement on the other, despite the fact that there can be no information exchanged between them.

For Einstein, this weirdness was an indication that something was missing from quantum theory. But these days, entanglement is just seen as a routine resource. Indeed, it no longer provokes any kind of head-scratching in the physicists who work with it on a daily basis.

"We cannot explain it in classical terms, but it's not really an issue somehow," says Mirjam Weilenmann, also at the University of Geneva. Ana Sainz, who works with entanglement at the University of Gdansk in Poland, feels similarly. "The fact that we don't see it in our macroscopic world every day makes it look weird, but I think it's just a fact of the universe," she says. ›

How to think about..

Entanglement is a key part of quantum computing

BARTLOMIEJ K. WROBLEWSKI/ALAMY

Actually, theorists showed in 2017 that entanglement simply has to exist for our universe to be as it is – it has nothing to do with the formulation of quantum theory itself. "Entanglement goes beyond quantum theory," says Sainz. "You can have entanglement even if quantum theory is false."

The phenomenon lies at the heart of several new kinds of technology. Even in its most basic form, "it can be super-useful for quantum computing and quantum cryptography, for example", says Artur Ekert at the University of Oxford.

Which isn't to say we understand everything about entanglement. "There are loads of open questions – some are really basic ones," says Sainz. One is simply how to measure the strength of entanglement. But although entanglement is often viewed as a mystery that holds the key to a better understanding of the universe at its most fundamental level, it might not work out like that, according to Ekert.

Entanglement has been touted as the underlying phenomenon that space-time itself emerges from, for example. And probing the phenomenon at high energies at the Large Hadron Collider at CERN, near Geneva, has recently been proposed as a route to figuring out what quantum theory tells us about the nature of reality.

But those who deal with entanglement every day are wary of such grand promises. It is already so intrinsic to our picture of the universe that there is no guarantee further experiments will reveal anything more, says Ekert. "There's much more to space and time than we understand," he says. "But is entanglement a manifestation of that? I don't know."

MB

CANCER

CANCER IS A DISEASE, or group of diseases, in which some cells proliferate uncontrollably and can spread to other parts of the body. But that description doesn't reflect how our conception of cancer has changed, says Kenneth Pienta at Johns Hopkins University in Maryland. "People used to view cancer as sort of bad luck: the cancer would just change over time and we didn't really understand why, or how, or what was driving those changes."

In the past few years, however, Pienta and others have come to see cancers as akin to organisms themselves, existing in complex ecosystems alongside other cancer cells and host immune cells. Cancer cells compete for access to nutrients, and only the fittest survive. "Cancer evolves in response to changes in its environment," says Pienta. "If it didn't, it would die."

Ultimately, this is the reason why cancer kills so many people. Cancer cells divide rapidly, so random mutations occur often and any that confer an advantage are quickly selected for. "They're evolving to become the best cancer cell they can become and that typically is bad news for the patient," says Robert Gatenby, co-director of the Cancer Biology and Evolution Program at the Moffitt Cancer Center in Florida.

What's more, the hardiest cells are better at getting into the bloodstream and spreading to other parts of the body, a process known as metastasis. "We have got good drugs and initial therapies for most types of cancers," says Gatenby. "But in the metastatic setting, you're almost never cured."

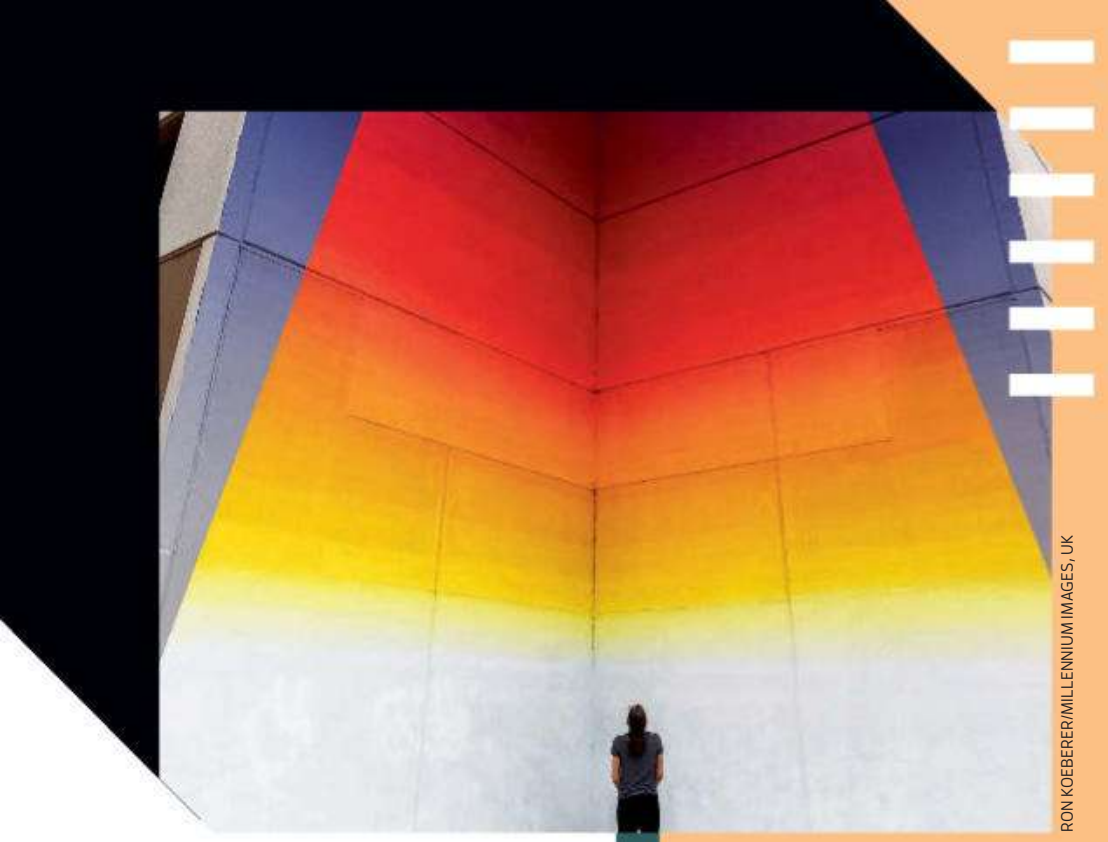
The good news is that viewing cancer through an evolutionary lens suggests new ways to treat it, says Gatenby. Among them is the idea that, rather than trying to wipe out cancer cells, we should manage the disease almost as if it were a chronic condition like diabetes.

Conventional treatments like chemotherapy or radiotherapy will always leave behind a small population of resistant cells. With their competition wiped out, they quickly proliferate – and the cancer becomes much harder to treat. However, Gatenby's lab is experimenting with ways to keep some treatment-responsive cells alive so that they compete with the resistant cells. "We only give a little bit of the treatment and then stop," says

STEVE GSCHMEISSNER/SCIENCE PHOTO LIBRARY/ALAMY

A cancer cell and two immune cells

How to think about...



RON KOEBERER/MILLENNIUM IMAGES, UK

Gatenby. "The tumour will come back, but because you're not applying any selection for resistance, the sensitive cells will dominate."

Another strategy could be to target cancer's ability to adapt. Pienta's team has discovered that when people are given chemotherapy, a tiny subset of cancer cells stops dividing and enters a state of hibernation. These polyaneuploid cancer cells can hide from chemo drugs. Pienta believes that by destroying them, we could collapse the whole cancer ecosystem.

It may even be possible to stop cancers before they have a chance to evolve. Charles Swanton at the Francis Crick Institute in London has found that when people experience chronic inflammation as a result of exposure to air pollution or tobacco smoke or alcohol, immune cells can kick-start cancer development. This opens yet another avenue of treatment: target the immune cells that cause cancers to grow in the first place. "The normal ecosystem is not subjected to the sort of genome instability that cancers are, so the targets are much more stable and potentially more tractable," says Swanton.

Ultimately, scientists believe that their new conception of cancer may allow us to cure it. "Our big advantage is that cancer cells can only adapt to the here and now," says Gatenby. "They can never anticipate the future. But humans can."

Jasmin Fox-Skelly

SCALE

IMAGINE SETTING OFF on a spacecraft that can travel at the speed of light. You won't get far. Even making it to the other side of the Milky Way would take 100,000 years. It is another 2.5 million years to Andromeda, our nearest galactic neighbour. And there are some 2 trillion galaxies beyond that.

The vastness of the cosmos defies comprehension. And yet, at the fundamental level, it is made of tiny particles. "It is a bit of a foreign country – both the small and the very big," says particle physicist Alan Barr at the University of Oxford. "I don't think you ever really understand it, you just get used to it."

Still, you need to have some grasp of scale to have any chance of appreciating how reality works.

Let's start big, with the cosmic microwave background (CMB), the radiation released 380,000 years after the big bang. "The biggest scales we've measured are features in the CMB," says astrophysicist Pedro Ferreira, also at the University of Oxford. These helped us put the diameter of the observable universe at 93 billion light years.

At the other end of the scale, the smallest entities are fundamental particles like quarks. Yet quantum physics paints these as dimensionless blips in a quantum field, with no size at all. So what is the shortest possible distance? The best we can do is the so-called Planck length, which is about 100 billion billion times smaller than a proton.

> "THE NUB OF THE PROBLEM IS THAT REALITY APPEARS TO OPERATE DIFFERENTLY AT VARIOUS SCALES"

This arises out of an idea in quantum mechanics known as Heisenberg's uncertainty principle, which says that certain pairs of properties, including position and momentum, can't both be known precisely at the same time. The upshot is that we can never measure anything beneath the Planck length, no matter how advanced our technology. Similar constraints apply to measuring other things, such as energy, too.

For physicists, though, the challenge goes way beyond just measurement. The nub of the problem is that reality appears to operate differently at various scales, making it maddeningly hard to pin down a unified description of everything.

Take the four fundamental forces of nature. The strong force binds quarks together to make subatomic particles such as protons and neutrons, the weak force corrals neutrons and protons in atomic nuclei, while the electromagnetic force keeps the whole atom together, electrons included. These three forces are way more muscular than the fourth – gravity. Even the weak force is 10^{24} times stronger than gravity. Naturally, physicists want to understand why there is such a huge discrepancy.

How to think about...

To make matters worse, we are also forced to use separate theories to describe these forces. Albert Einstein's theory of general relativity describes gravity on the scale of stars and galaxies. Meanwhile, the other three forces are governed by quantum mechanics, which applies to the subatomic realm. We have yet to find a way to meld the two into a theory of quantum gravity. "One of the biggest problems in physics is the disparity in scales between the size of atoms and the size of the universe," says Barr.

Perhaps our struggles with scale are telling us something deeper about the universe. Maybe, at the fundamental level, there is no scale at all.

That is the idea being pursued by Manfred Lindner at the Max Planck Institute for Nuclear Physics in Germany via a hypothesis called "scale symmetry". The basic idea is that scale is "emergent", in the sense that it arises from the collective effect of more fundamental entities for which scale is meaningless. "At the end of the day, all scales in nature are a quantum effect," says Lindner. ▮

Chen Ly

The back pages

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Stargazing at home

Night shining clouds

Long summer nights are the perfect time to spot the electric blue wisps of rare and beautiful noctilucent clouds, says **Abigail Beall**

Abigail Beall is a features editor at *New Scientist* and author of *The Art of Urban Astronomy. Follow her* @abbybeall

THERE are two things you usually need for stargazing: dark skies and clear skies. But if you live in the northern hemisphere like me, this isn't the time of year for dark skies. And if you live in the north of the UK, as I do, clear skies are never a guarantee. This is why this week I will be talking about a specific type of cloud you can look for during long summer nights.

Noctilucent clouds, also known as polar mesospheric clouds, are a rare kind of cloud that shine a silvery blue colour against the darker night sky. This is where their name, which means "night shining", comes from.

This beautiful phenomenon is created by ice crystals that form on dust particles in thin clouds. The particles are thought to come from tiny bits of space dust in the mesosphere, the third highest layer of the atmosphere. The clouds can come in many shapes – thin strings, thicker bands, waves or whirls. They only form during summer, because this is when the mesosphere is coldest. The fact they sit so high up in the sky, at about 50 to 86 kilometres from the surface of the planet, means these clouds can be lit by the sun long after it has set.

The best time to see noctilucent clouds is between an hour and a half to 2 hours after sunset, and the closer you live to the pole the better your chances. In the northern hemisphere, they start to be visible around the end of May, and it is possible to see them until the end of August. If you live in the southern hemisphere, they tend to appear between November and February.

DEW/ALAMY

You don't need any special equipment, just a bit of patience and a clear view of the northern horizon. Noctilucent clouds will appear in the west at first, then move north before eventually being visible in the east, just before sunrise. They move in this way because they are usually forming at the poles.

If you look just after sunset, you might first see a golden streak or two near the horizon before the pale, silvery blue shine of the noctilucent clouds appears higher up in the sky. These wispy, electric blue clouds will move around, creating patterns like the aurora, but at a much slower pace. If you use binoculars, you will see the patterns in more detail.

Like the aurora, there are websites and apps, such as CloudSpotter, that you can keep an eye on to increase your chances of spotting these rare clouds. Lots of noctilucent cloud spotters use social media to post when they see them – there are even X accounts for noctilucent cloud alerts.

If you don't see them the first time you look, there will be plenty more opportunities. Events like rocket launches can increase your chances, as they emit dust and gas that ice crystals can then latch onto, and a study in 2018 found that increasing greenhouse gases in the atmosphere is also making sightings more common. ▮

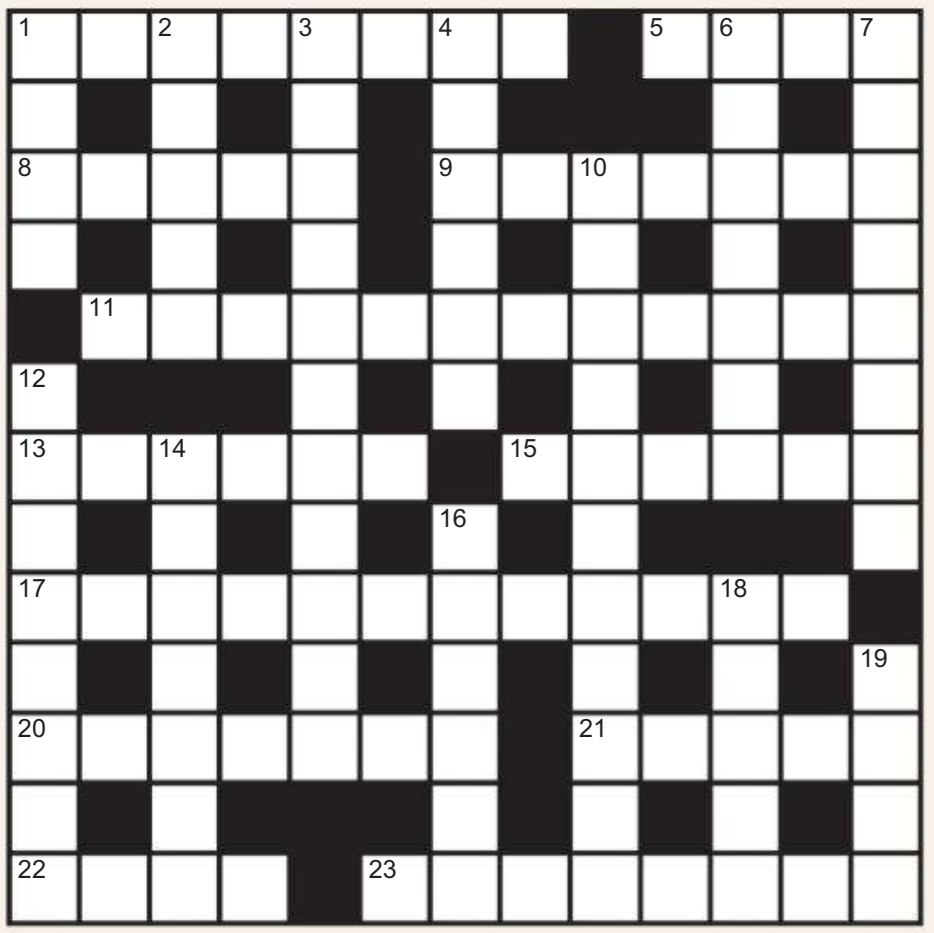
Stargazing at home appears every four weeks. Share your stargazing successes with us on X and Instagram @newscientist, using the hashtag NewScientistStargazing

These articles are posted each week at newscientist.com/maker

Next week

Mathematics of life

Cryptic crossword #136 *Set by Rasa*



Scribble zone

Answers and the next quick crossword next week

ACROSS

1 Large current runs through unfriendlier physicist's apparatus (8)
5 Outlaw beginning to believe critical remark (4)
8 Scene 5 is oddly trad (5)
9 Tabitha improved range (7)
11 Tighter exercises incorporating trig variable achieve a goal (3,3,6)
13 Regretted crossing street showing signs of deterioration (6)
15 Tavern fills a blue scoop (6)
17 Even Avenger from Asgard essentially prized farther boundary (5,7)
20 Ray wiggling nub into line of stitches (7)
21 Motorcyclist getting hot for British person on foot (5)
22 Persistently question shoe choice (4)
23 Droopy-eared hound eats in bed (8)

DOWN

1 Give half of evacuees flip-flops (4)
2 We hear Scots girl blended beverage (5)
3 I'm extra excited about the first-rate cinema (4,7)
4 Agreed with City of London and broke some ground (6)
6 Cooked tagine contains no lymphocyte trigger (7)
7 That boy's repaired tub accessories (4,4)
10 Forensic lamps have zero defects, per Spooner (5,6)
12 Dine after retiring noble captain slowly rises (6,2)
14 Simple calculation involving seabird bone (7)
16 Helpful robot manipulated a broom (6)
18 Noah's content with doll made of a durable wood (5)
19 Very dry except around mid-afternoon (4)

Our crosswords are now solvable online
newscientist.com/crosswords

Quick quiz #253
set by Bethan Ackerley

1 In particle physics, how many generations of quarks are there thought to be?

2 The moon Naiad orbits which planet?

3 How many pairs of cranial nerves are there generally thought to be?

4 The Kaikō, Nereus and Fendouzhe vehicles all visited which place?

5 Who invented the difference engine, a precursor to the first general-purpose computers?

Answers on page 47

BrainTwister
set by Katie Steckles
#21 Digit gangs

If we use the digits 0–9 in place of the letters A–J (in some order) in the numbers ABC, DE, FGH and IJ, we can create four numbers to use in calculations. For example, the numbers could be 134, 50, 289 and 67, or 013, 56, 289 and 74.

What is the largest total you can make for ABC + DE + FGH + IJ by assigning the digits?

Can you assign the digits to maximise the value of (ABC × DE) + (FGH × IJ)? What is the largest total you can get?

How can you assign the digits to make the value of (ABC × DE) – (FGH × IJ) as close to zero as possible?

Solution next week

Twinkle twinkle

What would we see, and how would Earth be affected, if Sirius, the brightest star in our night sky, were to go supernova? Would it be over in a blink or a decade? And would it be visible in daylight?

Mike Follows
Sutton Coldfield, West Midlands, UK

Sirius is a binary star system that is only 8.611 light years from Earth, comprising a main sequence star of a type larger than our sun and a white dwarf. If one went supernova, there is little doubt that it would be visible even in daylight and would certainly cause a mass extinction on Earth, so you wouldn't be around for long to admire it. Supernovae can briefly outshine the rest of their galaxy and stand out from their background stars for months.

Supernovae come in different varieties. Stars that begin life with at least eight times the mass of our sun explode when they run out of fuel. This is known as a type II supernova. A white dwarf that is part of a binary star system can explode in a type Ia supernova. This occurs when it sequesters material from its companion,

"Thankfully, Sirius B, which is a white dwarf, is too far from Sirius A to siphon off enough mass to become big enough to explode"

typically a red giant, and reaches a critical mass known as the Chandrasekhar limit, which is about 1.44 times that of our sun. Thankfully, Sirius B, which is the white dwarf in the Sirius binary system, is thought to be too far from its companion, Sirius A, to siphon off sufficient mass for this.

The appearance of a supernova and its effect on Earth life depends on its mass and distance from us. In the Milky Way, there is typically one supernova every 50 years. We would expect them to occur closer to us as Earth passes through the spiral arms of our galaxy, as these regions contain more short-lived massive stars.

The potential damage from a supernova gets delivered in instalments. Neutrinos carry away most energy from a supernova and they pass harmlessly through matter. Their arrival coincides with gamma rays, X-rays and visible light, which increases the brightness of the exploding star by a factor of 10 to 100,000. If the supernova were within 20 light years, this would destroy up to half of our ozone layer, leading to a mass extinction event.

It can take thousands of years for matter from the blast, including the particles that make up cosmic rays, to arrive. Although they only account for 10 per cent of the supernova energy, cosmic rays could cause a mass extinction from up to 50 light years away.

A supernova up to 100 light years away may have been responsible for the climate cooling that took place at the start of the Pleistocene epoch around 2.7 million years ago. This coincides with the change in habitat in Africa, when grasslands spread and forests declined, which may have favoured the appearance of *Homo habilis*, the first species in our genus, around the same time.

A supernova 41,000 years ago and 250 light years away probably resulted in the extinction of the mammoth. The gamma radiation and neutrinos would have taken just 250 years to reach us. It took another 7000 years for radioactive iron-rich grains from the blast to pepper Earth, seen as tiny impact craters on mammoth tusks.

Mercifully, there are no obvious supernova candidates close enough to threaten life on Earth.

Herman D'Hondt
Sydney, Australia

Let me start by saying that, with a mass of only about twice that of the sun, Sirius [A] isn't expected to go supernova. Such stars need about eight solar masses to blow.

If it could and did go supernova, it would definitely be visible in daylight. The most recent such explosion in the Milky Way was observed by Johannes Kepler in 1604. It was visible in daylight, even though it was about 20,000 light years away from Earth.
As Sirius is only about 8.7 light years from us, it would make an impressive display. The actual explosion takes only seconds, but the brightness would seem to increase over several days, and then gradually get dimmer over months. The duration varies with the type of supernova.

To be safe from a supernova we would need to be at least 150 light years away. Any closer, and we would start feeling the effects. At 30 light years, X-rays and gamma rays from the blast can destroy Earth's ozone layer, which protects life from solar UV radiation. This would cause mass extinctions.

Considering the frequency of supernovae, this has probably happened a few times. It is estimated that around 20 have occurred within 1000 light years of Earth in the past 10 million years, and a supernova at just 30 light years is expected every 250 million years. There is evidence, through the discovery of the unstable iron-60 isotope in deep-sea and lunar deposits, as well as in Antarctic ice, that one happened relatively close to the solar system between 2 and 3 million years ago. This form of iron is made in some stars and flung out by such explosions. This

SHUTTERSTOCK/KRASOWIT

Could we create a miniature version of the atomic bomb, one that creates a tiny blast?

This week's new questions

Going nuclear **Is there a minimum size for an atomic bomb? Would it be possible to make a microscopic one that results in a very small explosion? *Ray Smith**, Guyra, New South Wales, Australia*

In a spin **Are humans the only animal to experience vertigo?** ***Bryn Glover**, Kirkby Malzeard, North Yorkshire, UK*

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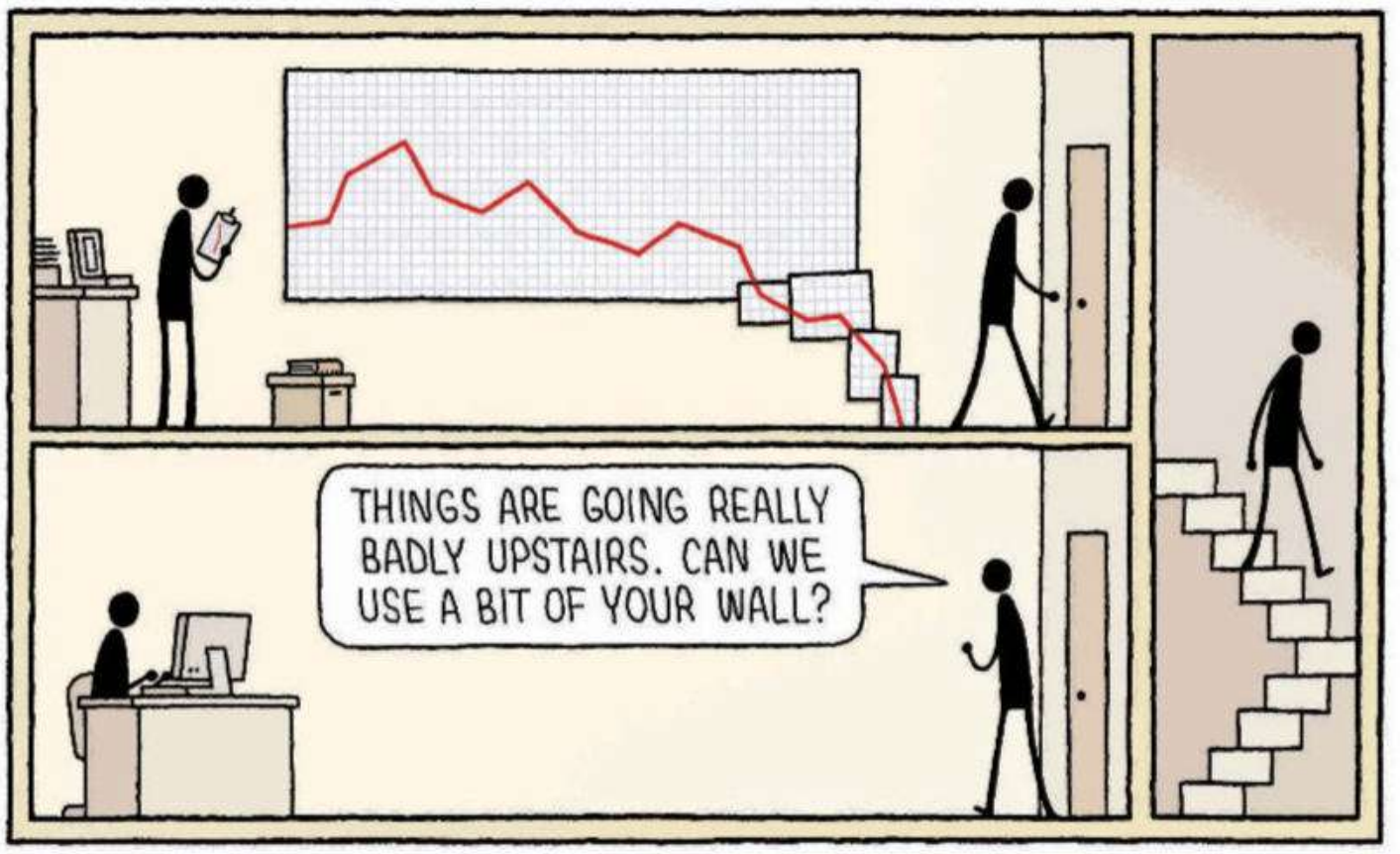

particular supernova is estimated to have been about 200 light years away, but may still have led some large marine animals to go extinct.

Edward Anderson
via Facebook
There would be sirius implications!

Timing it right

If Stonehenge is a giant calendar, how did the ancient Britons measure the length of days precisely enough to put the Heel Stone in just the right place to mark the solstices? (continued)

Donald A. Windsor
Norwich, New York, US
Trial and error is how. I turned my house into a calendar by marking the shadows cast on the solstices and the equinoxes. My house faces south, so I record the noon shadow cast by the roof on the floor at the summer solstice and way up on the wall at the winter solstice, also for the equinoxes. The sun rarely shines on the winter solstice, so it took several years to refine my

"I turned my house, which faces south, into a calendar by marking the shadows cast on the solstices and the equinoxes"

marks until they stabilised.

Stonehenge was probably done by marking sunrises and sunsets with wooden stakes, refining their location over time and moving the Heel Stone accordingly. When the marks stabilise, they could replace the wood with stones.

Buzzing off

How come, when the front door of my house is open, a fly can enter my home easily, but not escape as easily out of the same door? (continued)

Anthony Woodward
Portland, Oregon, US
There are many flies outside a house. The area of the walls of the house is much greater than the area of the doorway and most flies will hit the walls, but because there are so many flies outside there is a reasonable chance one will hit the doorway and enter the house.

Inside the house, the total area of the walls is much greater than the area of the door. The chance of one fly moving randomly hitting the doorway is small.

Ian Daniells
Kootingal, New South Wales, Australia
With only one door open, your house is a fly trap. The insects are drawn in, perhaps by the smell of cooking. They try to escape towards light, but don't grasp that glass is solid. You could open a door on the other side of your house. Oh, hang on; that won't work if you are cooking; more flies will come in. In Australia, we have fly screens on windows and doors. That keeps insects out (and in!).

A Fly (aka Steve Tees)
Chelwood Gate, East Sussex, UK
Why do humans open doors to let me in and then immediately want me to leave? ▮

Answers

Quick quiz #253 *Answers*

1 Three
2 Neptune
3 12
4 Challenger Deep in the Mariana Trench
5 Charles Babbage

Quick crossword #158 *Answers*

ACROSS 6 Faculty, **7** Preterm, **9** Banks, **10** Radiation, **11** Leopard, **13** Almond, **15** Herpes simplex, **19** Census, **20** Tinamou, **23** Chilblain, **24** Minus, **26** Pledget, **27** Element

DOWN 1 Icon, **2** Plasma, **3** Hybridise, **4** Teraflop, **5** Peritoneum, **6** Fibula, **7** Pads, **8** Monads, **12** Ocean liner, **14** Oil tanker, **16** Plumbago, **17** Ice cap, **18** Subset, **21** Number, **22** Watt, **25** NREM

#20 Factor-finding mission *Solution*

The first four primes are 2, 3, 5 and 7, and their product is 210, giving it four prime factors. Every other factor of 210 can be made by multiplying some of the prime factors together. Each prime factor can be either included or not in the multiplication, so there are $2 \times 2 \times 2 \times 2 = 16$ factors: 1 (the case when no prime factors are included), 2, 3, 5, 6, 7, 10, 14, 15, 21, 30, 35, 42, 70, 105 and 210). The next number with16 factors is surprisingly close – 216 is $2^3 \times 3^3$, which means its factors are made up of 0, 1, 2 or 3 of each of the two prime factors. This gives $4 \times 4 = 16$ factors (1, 2, 3, 4, 6, 8, 9, 12, 18, 24, 27, 36, 54, 72, 108 and 216). The lowest number with 16 factors is 120, $2^3 \times 3 \times 5$.

Distinguished frogs

It turns out, say Chatmongkon Suwannapoom and Maslin Osathanunkul, that a good way to distinguish one kind of fanged frog from another is to do melting analysis.

Their report, "Distinguishing fanged frogs (*Limnonectes*) species (Amphibia: Anura: Dicroglossidae), from Thailand using high resolution melting analysis", explains how they achieved the "rapid and accurate identification of six species of *Limnonectes* of the *L. kuhlii* complex".

The thing they melted was a specific region of RNA from the ribosomes of each frog. Plotting the temperatures at which the frogs' ribosomes' RNA does or does not melt creates a separate, easily distinguishable curve for each kind of frog.

Eyeballing, the technologically simpler technique used by frog scientists back when frog scientists were called "naturalists", has its limits. Melting exceeds some of those limits.

Twisteddoodles *for New Scientist*

Got a story for Feedback?

Send it to feedback@newscientist.com
or New Scientist, 9 Derry Street, London, W8 5HY
Consideration of items sent in the post will be delayed

Cats on cannabis

The full effects of cannabis – like, come to think of it, the full effects of anything – on humans still hold some mysteries.

So it is with cannabis and cats. Chloe Lyons and her colleagues at the University of Saskatchewan, Canada, have made some progress about the cats.

Writing in *Frontiers in Veterinary Science*, they describe what happened when they gave 12 cats two oral doses of a cannabis herbal extract (the acronym for which is CHE). Some cats received a dosage more than double what the others got.

Reader Stefan Lalonde points out a study highlight: a photo of a lavishly drooling cat. A second cat also drooled. The report states: "these two cats clearly hypersalivated".

The scientists express surprise about the cats: "Salivation shortly after dosing was observed in two cats in the high dose group; these animals had substantially lower cannabinoid concentrations than other cats in this group."

The team speculates about the mechanism that caused the drooling. "Cats are notorious for 'spitting up' oral medications which they conceal in their oral cavity, and it could not be confirmed that all cats swallowed the entire CHE dose," the researchers write. "Any oil-based CHE retained in the oral cavity may have prompted the cat to salivate, and subsequently been expelled from the mouth."

This unexpected twist in the who-drools data hints that the relationship between hunger and cannabis consumption in cats may be complex.

Or that these two particular cats were eccentric, one way or another.

A sticky issue

At sea, there is spice. Feedback still delights in how oceanographers decided that some ocean water can be called "spicy" and other ocean water "minty" (8 October 2022). Here's further delight: in the air, there is "stickiness".

Reader Earle Spamer brings news of the latter. "Here's a paper that brandishes a 'new' variable in climate studies: stickiness," he writes. "An awful lot of mathematics to explain what my grandmother knew just by sitting on the front porch."

The paper is "Stickiness: A new variable to characterize the temperature and humidity contributions toward humid heat" by Catherine Ivanovich at Columbia University and her colleagues, published in the *Journal of the Atmospheric Sciences*.

"We derive a novel thermodynamic state variable named 'stickiness'," they write. This is "analogous to the oceanographic variable 'spice' (which quantifies the relative contributions of temperature and salinity to a given water density)". Stickiness "quantifies the relative contributions of temperature and specific humidity" to the more traditional way of measuring temperature.

Word by common word, scientific specialties adapt familiar, sticky old ideas and names to help expose and explore the easy-to-overlook complexities of the universe.

Ketchup cardio claim

Feedback's recent insights on ketchup (16 March) set at least one reader's heart racing.

David Watson writes: "Years ago, before the advent of disposable adhesive electrodes, I was having an electrocardiogram [ECG]. The electrodes then were little rubber cups suckered onto your skin using a conductive gel. I remarked to the cardiologist that the gel was probably ridiculously expensive. He said it was, and a group had researched cheaper alternatives. They found one with the right combination of surface tension, viscosity and conductivity. Unfortunately, it was low on patient acceptability – ketchup, of course."

Documentation of that doctor's claim (which may have been just a jest) seems scarce. Feedback has so far found only a pooh-poohing, in a 1981 study by Andrew P. B. Lee, "Biotechnological principles of monitoring", published in *International Anesthesiology Clinics*.

Lee wrote: "Most electrode jellies sold are no more effective than K-Y jelly or tomato ketchup at lowering the skin-electrode impedance."

If you find convincing evidence in favour of ketchup's use as a conductive gel for electrocardiograms, please send it over. ▮

Marc Abrahams

Survey

NewScientist

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The survey prize draw is open to UK residents (excluding Northern Ireland) only and will close on 21 June 2024 at 11:59pm BST or after 10,000 people have completed the survey, whichever happens first. Only one entry per person will be accepted into the prize draw. Three winners will be drawn at random from the submitted surveys and will receive 1x£100 Amazon gift card each; prizes are as described, there is no cash alternative. For full terms and conditions see newscientist.com/terms-and-conditions-for-free-prize-draw/

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